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# SPROUTING, PLANT GROWTH, AND TUBER PRODUCTION AS AFFECTED BY CHEMICAL TREATMENT OF WHITE POTATO SEED PIECES.

## II. EFFECT OF TEMPERATURE AND TIME OF TREATMENT WITH GIBBERELLIC ACID.[1]

HERMAN TIMM, LAWRENCE RAPPAPORT, PAUL PRIMER, AND O. E. SMITH[2]

In certain sections of the United States, and in various other countries, it is often necessary to treat freshly harvested seed with a chemical to shorten rest, or to import dormant seed for a second crop. In California, seed harvested in the spring may be replanted in July and August for a fall crop, or fall harvested tubers may be treated to induce sprouting for tuber indexing. Ethylene chlorohydrin, heretofore the most important chemical used to shorten rest, is barred by law because it is highly toxic to man and a substitute is needed.

Gibberellic acid applied as a foliage spray, or as a dip treatment to whole potatoes, has been reported to shorten the rest period[3] and to promote sprout elongation of potatoes (2, 3, 4, 6, 8, 14, 16, 17, 18, 20). Under field conditions foliar applications induced sprouting of growing tubers on the treated plant (7, 8, 17, 18). A five-minute dip in solutions containing as little as 1 ppm of gibberellic acid induced sprouting of freshly harvested tubers; sprouting rate was markedly influenced by temperature (16).

While these previous studies provide knowledge on the physiological action of gibberellic acid, the possible commercial use for shortening the rest period was not discussed. Marked inconsistencies of many plant species in response to gibberellic acid (1, 9, 15) made necessary a consideration of the effects on potato sprouting and yields of concentration, age of seed, and temperature.

### PROCEDURES AND RESULTS

In this and previous reports "visible sprouting" and "emergence" are treated as distinctly different events. Visible sprouting refers to the appearance of the first elongating sprout at an eye. Emergence refers to appearance of a plant above the soil, which is necessarily influenced by variables of culture, moisture, and temperature.

Field and controlled-temperature storage studies were conducted in 1957 and 1958 with seed at various stages of rest, but not sprouting at the time of treatment. In the field studies, White Rose, Kennebec, Pontiac,

[1]Received for publication May 23, 1960. Appreciation is expressed to Merck & Co., Inc., and Abbott Laboratories, who generously provided financial assistance. The gibberellic acid used was the potassium salt of gibberellic acid (Gibrel), kindly supplied by Merck & Co., Inc.

[2]Assistant Olericulturist, Assistant Olericulturist, Laboratory Technician and Graduate Assistant, respectively, Department of Vegetable Crops, University of California, Davis, Calif.

[3]Rest period is defined as the period immediately after harvest in which no sprouting occurs even under optimal sprouting conditions (5). Dormancy is a period following the rest period in which no sprouting occurs if environment is not favorable.

and Russet Burbank potatoes were planted 12 inches apart in the row in a randomized block design in Kern, Yolo, and Siskiyou counties. Each treatment was replicated three or four times and planted by machine or by hand. Cultural practices other than row and seed spacing were similar to those shown to be best for each area (10). To facilitate making measurements, wider rows and seed spacing than usual were used, which in part accounts for relatively low yields (see Table 1). Gibberellic acid was applied by dipping whole tubers for five minutes in solutions containing the desired concentration. After air drying, seed was cut into 1½- to 2-ounce pieces, which were placed in storage for 24 hours before planting at 68° F, 80 to 90% relative humidity, a condition optimal for suberization.

In the first field experiment at Davis, White Rose, Kennebec, Russet Burbank, and Pontiac potatoes grown at Davis were harvested July 23, 1957 and held at 59° F. On August 6 tubers were treated with water (0 ppm) or solutions containing 1, 5, or 25 ppm of gibberellic acid and planted the next day 4 to 6 inches deep in a randomized block with 4 replications. Chemical treatment hastened emergence and increased the total number of plants of the 4 varieties, Fig. 1. White Rose and Pontiac were more responsive than Kennebec and Russet Burbank. Yields of the 4 varieties were increased, but were low (Table 1), probably as a result of late tuber set and short growing season. The relatively high coefficient of variability in the Kennebec and White Rose varieties is attributable to differences in stands between replications.

Another experiment at Davis evaluated the effect on sprouting of storage before chemical treatment. White Rose potatoes harvested July 23 and held at 59° F. were divided into 5 lots on August 6, 1957. One lot, treated immediately with solutions containing 0, 1, 5, and 25 ppm of gibberellic acid, was cut and planted 8 to 10 inches deep in prepared hilled and fertilized beds spaced 42 inches apart. The remaining lots were held at 59° F. controlled temperature. A lot was withdrawn biweekly, treated, and planted. A latin-square design was used with 4 replications, 10 seed pieces each. Rate of emergence was recorded, but not tuber yields, because of the short time before killing frost, early in November. Only data for the first and third planting dates are shown (Fig. 2); high soil temperatures caused excessive seed-piece breakdown in the second planting, and gibberellic acid had little effect on emergence in the final planting. Gibberellic acid treatment markedly stimulated emergence in the first planting, but had no effect in the later planting.

Sprouting and yield responses of field-grown potatoes were further investigated in two experiments in 1958, Table 2. White Rose tubers from plants killed by frost were harvested on November 7, 1957 and held in common storage at 45°-50° F They were treated on December 10 with solutions containing 0, 0.1, 0.5, 1, 5, and 10 ppm of gibberellic acid. They were cut into 2-ounce seed pieces and planted 6 inches deep, spaced 12 inches apart in 32 inch wide beds on December 13 at Arvin, Kern County, in a randomized block design. Kennebec potatoes, harvested at Shafter on June 18, were held at Davis at 59° F. until August 9. They were treated with 0, 5, and 10 ppm then cut and hand planted in 42 inch beds spaced 12 inches on August 12. The effects of gibberellic acid on number of stems per hill, yield, and specific gravity are shown in Table 2. The new crop was harvested after 154 days at Arvin and after 108 days at Davis.

TABLE 1.—*Total yields of tubers after seed-piece treatment with various concentrations of gibberellic acid.*

Treated and planted August 6 and harvested November 6, 1957, at Davis. (Average of 4 replications of 25 plants each.)

| Gibberellic acid | Average Yield—Cwt. Sacks/Acre* | | | |
|---|---|---|---|---|
| | White Rose | Kennebec | Pontiac | Russet Burbank |
| (ppm) | | | | |
| 0 | 20.2 | 2.9 | 25.5 | 7.1 |
| 1 | 78.8 | 19.8 | 73.2 | 26.2 |
| 5 | 48.9 | 26.0 | 57.8 | 32.8 |
| 25 | 70.0 | 31.4 | 56.1 | 21.2 |
| L.S.D. 5% | N.S. | N.S. | 14.4 | N.S. |
| C.V. (%) | 28.2 | 41.8 | 13.3 | 22.7 |

*Only the results of the gibberellic acid treatments were compared statistically.

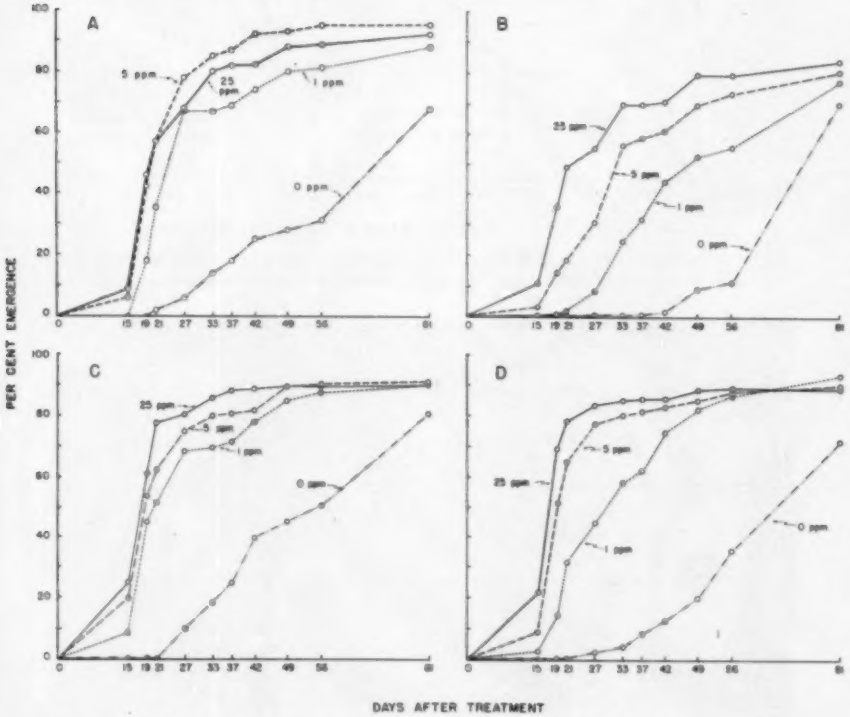


Fig. 1.—Effect of gibberellic acid treatment of seed pieces on per cent plant emergence. A. White Rose, B. Kennebec, C. Pontiac, D. Russet Burbank. Seed planted on August 6, 1957 at Davis.

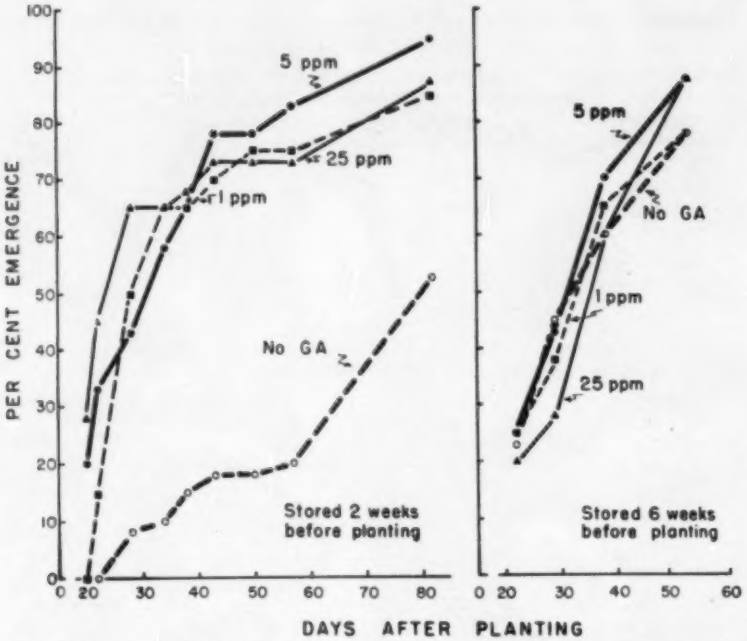


Fig. 2.—Emergence of White Rose potatoes after treatment with gibberellic acid. Seed was stored for 2 and 6 weeks at 59° F. before it was treated and planted.

Gibberellic acid stimulated sprouting in both locations, but yields were increased only at Davis. No difference in number of stems per hill was found at either location. Although gibberellic acid induced earlier emergence at both locations, the longer growing season and lower soil temperature at Arvin no doubt nullified the advantage of earlier plant emergence. At Davis, with a shorter but warmer season, treatment with gibberellic acid resulted in increased yields. The mean soil temperatures at Arvin and Davis for the first 30 days after planting were respectively 45° and 70° F. Specific gravity of tubers was not affected at Arvin, and the lower specific gravity of tubers from the control than from treated plants at Davis was most likely due to their relative immaturity.

Another experiment tested the effects of temperature and time of treatment on sprouting response to gibberellic acid. On July 8, 1958, three weeks after harvest, White Rose potatoes were divided into 5 lots (Fig. 5). Half the tubers in each lot were treated before storage with water or 5 ppm of gibberellic acid, cut, and held at 77° F. after receiving the following storage treatments: 1) No storage (Fig. 5A); 2) Storage at 41° (Fig. 5B) or 77° F. (Fig. 5C) for 2 weeks; and 3) Storage at 41° (Fig. 5D) or 77° F. (Fig. 5E) for 4 weeks. The other half of each lot was treated after storage. Sprouts were counted every 6 days. Seed pieces were considered sprouted when a sprout was 1 cm long.

The promotion of sprouting by gibberellic acid was influenced by time of treatment and storage temperature. Treated and untreated tubers of Fig. 5A began sprouting almost simultaneously, but gibberellic acid pro-

TABLE 2.—*Effect of gibberellic acid on stem count, yield, and specific gravity of White Rose and Kennebec tubers.*

| Trial location* | Variety | Gibberellic acid | Number stems per hill | Yield cwt. sacks per acre | Specific gravity |
|---|---|---|---|---|---|
| | | (ppm) | | | |
| Arvin, Kern Co. | White Rose | 0 | 1 | 288.7 | 1.080 |
| | | 0.1 | 1 | 283.8 | 1.080 |
| | | 0.5 | 2 | 295.2 | 1.079 |
| | | 1 | 1 | 316.4 | 1.081 |
| | | 5 | 1 | 352.3 | 1.080 |
| | | 10 | 2 | 321.3 | 1.081 |
| | | L.S.D. 5% | | N.S. | N.S. |
| | | C.V. (%) | | 12.6 | 2.7 |
| Davis, Yolo Co. | Kennebec | 0 | 1 | 117.6 | 1.067 |
| | | 5 | 1 | 273.7 | 1.076 |
| | | 10 | 2 | 295.4 | 1.077 |
| | | L.S.D. 5% | | 60.3 | 0.003 |
| | | 1% | | 100.1 | 0.005 |
| | | C.V. (%) | | 12.3 | 1.7 |

*Arvin, planted December 13, harvested May 13; Davis, planted August 12, harvested November 25.

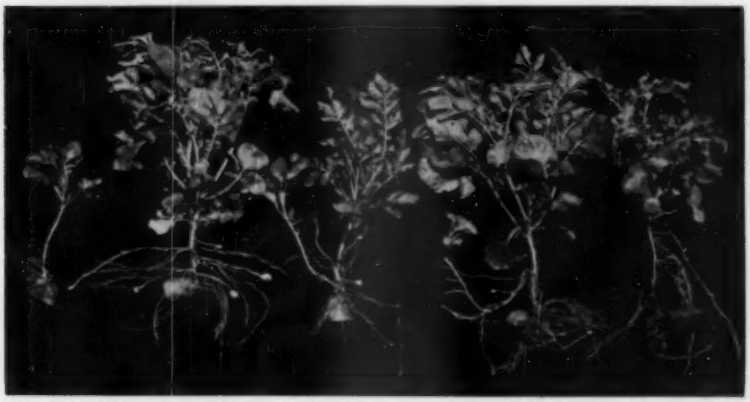

Fig. 3.—Effect of gibberellic acid treatment to seed pieces on subsequent plant growth and tuber development. Left to right: 0, 0.5, 1, 5, and 10 ppm gibberellic acid. Note the elongated stolons and decreased tuber set paralleling increases in concentration. Photographed 60 days after planting at Tulelake, Siskiyou County.

FIG. 4.—Effect of gibberellic acid on shape of White Rose potato tubers. Top to bottom: 0, 5, and 10 ppm.

moted the rate of sprouting. Treatment resulted in 100% sprouting within 22 days, whereas only 75% of the untreated controls sprouted within 30 days. Holding at 77° F. (Figs. 5A, C, and E) reduced the sprouting percentage of untreated seed, whereas initial 2- and 4-week cold periods before transfer to 77° F., respectively, resulted in 100 and 88% sprouting (Figs. 5B and D). Gibberellic acid increased sprouting to 100% in all tubers held at 77° F. (Figs. 5A, C, and E).

Untreated seed stored at 41° F. and transferred to 77° F. sprouted faster after the first 6 days than seed held continuously at 77° F. Chemical treatment stimulated sprouting of tubers the first week after transfer from a 2- or 4-week exposure at 41° F. After 4 weeks at 41° F., however, both treated and untreated tubers sprouted at the same rate, after sprouting began. Seed treated before storage sprouted faster than seed treated after storage.

Treatment with gibberellic acid produced some interesting formative effects on plants and tubers. At Tulelake, Siskiyou County, plants from tubers treated with 5 or 10 ppm were practically devoid of new tubers two months after planting, whereas tubers treated at lower concentrations set normally, before those on the control plants (Fig. 3). Gibberellic acid frequently produced excessive stolon and stem elongation; occasionally, the elongated stolon produced leaves above the soil surface. Concentrations above 5 ppm promoted elongation of the stem ends of tubers, giving a pear-shaped or spindly effect, Fig. 4. Yields were not reported because of excessive damage by field mice.

## DISCUSSION AND CONCLUSIONS

The effect of gibberellic acid on emergence is conditioned by age and

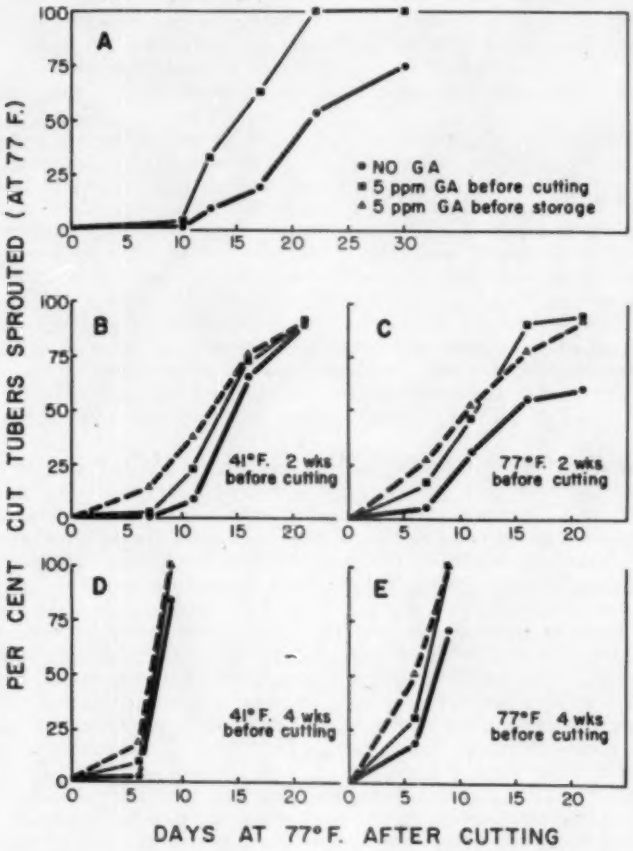


FIG. 5.—The effect of gibberellic acid on per cent sprouting of cut potato seed pieces held at 77° F. after the following storage treatments: A) No storage, cut and held at 77° F.; B) Stored 2 weeks at 41° F.; C) Stored 2 weeks at 77° F.; D) Stored 4 weeks at 41° F.; E) Stored 4 weeks at 77° F. Measured when sprouts were 1 cm. long.

time of treatment after harvest, soil temperature, and previous storage temperature. The stimulating effect decreases with time after harvest and with low soil or storage temperatures. This is emphasized by the striking effect of gibberellic acid applied 15 days after harvest on emergence of sprouts of four potato varieties at Davis, Fig. 1, and by the data of Fig. 2. Early emergence is undoubtedly the result of the combined effect of gibberellic acid on the rest period and subsequent stimulation of sprout elongation. These effects, described previously (6, 16, 17), decrease with time after harvest (Figs. 2 and 5).

Fig. 5 shows the influence on sprouting of temperature and time of seed treatment after harvest. Gibberellic acid promoted sprouting at 41° and 77° F. and increased the percentage of sprouted seed at 77° F. The greatest stimulation, however, was in tubers stored at the higher temperature.

Gibberellic acid is known to be a potent growth-promoting substance. Potatoes in particular are extremely responsive to low concentrations. Smith and Rappaport (18) showed that, under controlled temperatures, a concentration of gibberellic acid as low as 0.001 ppm was effective in curtailing the rest period. Differences in sprouting of the four varieties in response to gibberellic acid, Fig. 1, and the marked effect of temperature on plant emergence, Fig. 5, point to a need for careful evaluation of these factors under different environmental conditions. The present studies again showed the undesirable effects of high concentrations of gibberellic acid—elongation of stem internodes, elongation of stolons, delay of tuber and leaf development, chlorosis of foliage, and persistent effects of seed piece treatment on size and shape of new tubers—reported previously (2, 6, 7, 8, 11, 12, 13, 16, 17). These effects were less evident at concentrations of 5 ppm or below.

At Arvin, treated seed sprouted faster than untreated seed, although low soil temperatures had retarded sprouting for three months. This, coupled with the results of the controlled-temperature study at Davis, Fig. 5, indicates that the effect of gibberellic acid persists in tubers for a considerable time after treatment. It makes questionable the existence of a mechanism for destroying gibberellic acid in potato tubers.

How gibberellic acid affected yields is of interest. At Davis, with a relatively short growing season—108 days (Table 1)—it hastened emergence and increased yields of potato tubers. At Arvin, gibberellic acid was not found to increase yield, probably because all treatments were harvested after 154 days, a period longer than necessary to grow a commercial crop. Morgan and Mees (12) showed that foliar sprays of gibberellic acid on potato plants decreased tuber yields. Treatment of dormant seed pieces did not increase yield of a subsequent crop (unpublished data, Timm and Rappaport). This suggests that gibberellic acid increased yield indirectly by promoting early sprouting and plant growth. Since high concentrations of the chemical may delay tuber development, beneficial effect is maximum when nonsprouting tubers are treated with low concentrations and harvest is not delayed beyond a growing period normal for the variety. Concentrations above 5 ppm generally caused undesirable effects. The range from 0.1 to 5 ppm should be included in similar investigations in other locations. In California a concentration of 1 ppm gave optimal results. Within these limits it appears that this chemical may be of practical use in promoting the sprouting of resting seed. The desirability of using a compatible fungicide together with gibberellic acid is indicated in a recent study by Timm and Rappaport (19). Seed-borne *Rhizoctonia* may infect and cause a dieback of the main shoot. Seed treatment with gibberellic acid and corrosive sublimate in combination promoted emergence more than treatment with gibberellic acid alone.

## Summary

The effect of gibberellic acid on sprouting of potato seed pieces is

conditioned by the stage of rest period, concentration, temperature, and time after seed treatment. Sprouting response to gibberellin treatment decreases with time after harvest. Gibberellic acid promoted sprouting more at 77° F. than at 41° F. and consistently increased the total percentage of sprouted tubers at 77° F. In field studies, treatment of resting seed with concentrations of 5 ppm or less hastened plant emergence. In a normal growing season gibberellic acid treatment resulted in a larger subsequent crop without deleterious effects on plant growth or tuber characteristics.

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# EFFECTS OF ENVIRONMENT ON TUBER PRODUCTION, POTASSIUM ABSORPTION, AND SUSCEPTIBILITY OF POTATOES TO VIRUS DISEASE IN POLAND[1]

A. KOZLOWSKA[2]

It is well to know that tuber production of potato is strongly dependent upon the conditions under which the plants have been grown. Growers are very particular about where their seed potatoes come from, and they insist that they come from cool climates, otherwise the yield of the next generation is low. In the absence of viruses, potatoes grown under high temperature conditions show degeneration phenomenon, as a physiological response to the growing conditions of the parent generation, Gerlach (1), Werner (7), Gregory (2), Went (8).

In Europe the best regions for potato cultivation are situated along the Atlantic and Baltic Seas. West Pomerania, bounded by the Odra in the west and by the Vistula in the east, is one of the best regions for seed potato production in Central Europe. It is characterized by a low mean temperature during the vegetative period, namely 12° C. Although it has low precipitation yet it is the main humid region of Poland, in June the relative humidity of the air attains 80 per cent, Kozlowska (3). This terrain is covered with glacial deposits, mostly sand soil. Winds blowing from the Baltic Sea influence only sporadical invasion by aphids, which occur in small numbers towards the end of August.

Central Poland has a more or less continental climate, where such trees as beech and fir attain their eastern limit. In the neighborhood of Cracow, the average temperature of the vegetative period is 15° C. and rainfall and relative humidity of the air is lower than in Pomerania.

Crossing the Vistula at Cracow, one enters the Carpathians, the wide arc of which closes in Poland from the south and reaches in the Tatras up to the highest alpine zone. Together with the configuration of the terrain, the climate of central Poland, with a high mean temperature during the vegetative period, is subject to fundamental changes as one advances towards the Carpathians, precipitation during the vegetative period increases from 300 to 750 millimeters (April to September), whereas the mean temperature drops from 15° to 12° (April to September).

## MATERIALS AND METHODS

In 1955, two varieties of potatoes, Epoka and Ackersegen, were taken from Pomerania to various conditions of soil and climate in southern Poland, in the more or less lowland area near Cracow, and in the Carpathians. A total of 54 research points was established. The experimental fields were fertilized every year with manure, superphosphate, and potash salts.

This whole terrain, which is of complex geological structure may be roughly divided into latitudinal belts including the following: the Cracow Highland, covered mostly with loesses and sands on calcareous

[1]Accepted for publication March 24, 1960. An invitation paper presented at 43rd Annual Meeting of the Potato Association of America, University of New Brunswick, Fredericton, New Brunswick, Canada.

[2]School of Agriculture, Cracow, Poland.

substratum; the valley of the Vistula, with alluvial deposits; the external Carpathian region, covered with loesses, loams, and marls and attaining an altitude of 900 meters above sea level; the Magura Flysch of tertiary age, rising to 1725 meters above sea level and composed mostly of sandstones with heavy surface soils containing a high percentage of clayey substances; and farthest south the regions of Podhale and Tatras, built of limestones and crystalline rocks and attaining in its highest alpine peaks an altitude of 2663 meters above sea level.

The composition of the soil namely, percentage of clayey substance (montmorillonite and kaolin), humus, $CaCO_3$, sand, $K_2O$, $P_2O_5$, and pH. were indicated.

In the experiments, carried out for three consecutive years at all the experimental points, the state of health and the development of plants, representing the same clonal generations were determined. Every year, statistical methods were used in the estimation of the mean crop underneath one potato plant. Determinations were also made of total phosphorus and potassium in the dry ash of potato tubers (dry weight basis). Potassium was determined by flame photometry.

*Incidence of virus diseases.*

The incidence of virus diseases, leaf roll and streaks, was directly dependent upon the invasions of aphids. Lowland stations situated near Cracow and in the valley of Vistula, are generally more exposed to aphid invasion than are those in the Carpathian foothills. In the foothills health conditions are worse than in the Carpathian proper. In the mountains, the direction of the valleys, the altitude above sea level and the associated wind directions, are decisive with regard to the intensity of aphid invasion, exerting a direct influence upon the degree of health of the potatoes. Potatoes cultivated in the Carpathian foothills in valleys of rivers flowing from the south into the Vistula, especially in their lower courses, have the most leaf roll and streaks. High lying mountain stations open and exposed to wind action, are in danger of aphid invasion. even in the upper mountain zone of the Tatras, aphids were encountered on potatoes. On the other hand, potatoes in closed valleys, especially ones that run east and west, are almost devoid of aphids and virus infection. The same high degree of health is manifested by Carpathian stations situated on inclined mountain slopes at an altitude of approximately 800 meters above sea level.

*Development of potatoes at the investigated stations, 1955-1957.*

Pomeranian potatoes, when transferred to 54 stations in the lowlands and in the mountains at various altitudes above sea level displayed differences in development and crop in the first and following years of cultivation when only healthy plants were considered. Moreover. there was evident a certain regularity associated quite distinctly with altitudes above sea level.

During their first and second year in the lowlands near Cracow. where they had optimal conditions for development, Pomeranian potatoes developed and yielded higher than in Pomerania (Table 1). Under normal cultivation and fertilizing, their development was identical in loess and calcareous "rendzina", lower on sandy soils.

TABLE 1.—*Mean crops per plant of the variety Epoka and $K_2O$ content in tubers (dry weight basis), grown at 23 experimental stations in different climatic conditions, after second year of cultivation (1956) and transferred to Cracow (1957).*

| Locality | Altitude meters above sea level | Mean daily temperature July-Sept. | Yield dkg | $K_2O$ Per cent | 1957 Transferred to Cracow | |
|---|---|---|---|---|---|---|
| | | | | | Yield dkg | $K_2O$ Per cent |
| **South Poland lowland** | | | | | | |
| Cracow-Zwierzyniec | 207 | 15.8 | 107 | 1.85 | 54.1 | 2.12 |
| Pszczyna | 250 | 15.5 | 111.3 | 1.56 | 78.8 | 2.36 |
| Polanowice | 260 | 15.7 | 91.7 | 2.57 | 125.16 | 2.41 |
| **Carpathian foothills** | | | | | | |
| Lodygowice | 350 | 14.9 | 91.9 | 1.96 | 99.6 | 2.21 |
| Miedzyswieć | 351 | 15.6 | 128.5 | 2.72 | 69.8 | 2.54 |
| Jawornik | 375 | 15.6 | 62.5 | 2.72 | 60.14 | 2.30 |
| Targanica | 400 | 16.3 | 101.2 | 2.16 | 42.3 | 2.50 |
| **Carpathian mountains** | | | | | | |
| Lubień | 440 | 14.5 | 56.4 | 2.32 | 95.5 | 1.86 |
| Tenczyn | 550 | 14.0 | 83.2 | 2.18 | 105.3 | 1.88 |
| Ludzmierz | 580 | 13.8 | 50.7 | 2.40 | 82.8 | 1.88 |
| Istebna | 600 | 13.2 | 36.8 | 2.38 | 43.5 | 2.06 |
| Harklowa | 600 | 14.7 | 67.6 | 2.36 | 82.8 | 2.10 |
| Raba Wyzna | 630 | 14.8 | 40.3 | 2.43 | 87.9 | 1.97 |
| Zawadka | 690 | 14.3 | 57.8 | 2.28 | 97.9 | 1.94 |
| Kluszkoece | 710 | 13.8 | 56.0 | 2.30 | 120.3 | 1.90 |
| Naprawa | 720 | 13.2 | 34.3 | 2.32 | 55.2 | 1.94 |
| Wisla | 777 | 13.1 | 36.8 | 2.19 | 106.2 | 2.00 |
| Magórka | 900 | 13.0 | 47.7 | 2.10 | 103.5 | 1.46 |
| Turbacz | 1000 | 10.6 | 34.9 | 2.44 | 96.05 | 2.08 |
| Zakopane-Gubalowka | 1008 | 12.0 | 38.6 | 2.64 | 72.2 | 2.16 |
| Tatry-Mala Laka | 1070 | 10.6 | 3.9 | 3.00 | 61.18 | 1.88 |
| Tatry-Kopieniec | 1292 | 10.0 | 8.63 | 3.03 | 93.8 | 2.16 |

A quite sudden check in the development of the plants and a decrease of the crop occurred in association with the development of virus diseases, particularly in the third year of cultivation.

In the mountain region of the Carpathians, Pomeranian potatoes in the first year of cultivation, yielded poorly and had a low habit of growth. The decrease in yield per 100 meter increase in altitude, for variety Epoka, taking into consideration 43 experimental fields, amounted to 44 g for one single plant.

The decrease in yield per 100 meter increase in altitude for variety Ackersegen amounted to 59 g for one single plant. These coefficients of regression are statistically significant at the confidence 1 per cent level.

It must be stated that in accordance with the difference in elevation

the mean daily temperature during the vegetative period decreased and in the Carpathians high mountain experimental fields was less than in Pomerania.

Nevertheless the above mentioned negative correlation between yield and altitude can by no means be considered as an absolute rule. In three cases where Epoka was grown between 580 and 840 meters above sea level, the mean yield of tubers per plant was near 1500 g. These experimental fields, the data from which were not analyzed statistically, were situated on south inclined slopes covered with well aerated deep soil. Probably, the microclimate provided by the higher soil temperature of these places provided a physiological basis for the development of the potato plant.

The $K_2O$ and $P_2O_5$ content in the potato tubers in the first year of cultivation at all experimental points varied within the limits considered characteristic of potato tubers by many investigators, Kroner and Volksen (4), Ward (5) and also characteristic of the initial Pomeranian potatoes: $K_2O$ from 1.50 per cent to 2.58 per cent and $P_2O_5$ from O.463 per cent to 0.660 per cent, dry weight basis.

Following several years of cultivation in the Carpathians the percentage of $K_2O$ in healthy tubers rose. The mean difference of $K_2O$ content in potato tubers of the variety Epoka, cultivated in the mountains in 1956 in comparison to 1955 was 0.32 per cent, which was significant at the 1 per cent level. The mean difference of $K_2O$ content in the same material between 1955 and 1957 was 0.52 per cent, and was significant at the same 1 per cent level. Simultaneously with the increase of $K_2O$ content in potato tubers, their yield decreased.

The coefficient of regression of $K_2O$ content of tubers of the Epoka variety from 42 Carpathian experimental fields in the second year of cultivation (1956) on single plant yields was significant at the level of 5 per cent. These data indicate that for each decrease of yield of 1 g per plant, the $K_2O$ content of their tubers increased 0.0045 per cent (dry weight basis). In the third year of cultivation (1957) for each decrease of yield of 1 g per plant the $K_2O$ content of their tubers increased 0.0035 per cent (dry weight basis).

In the first year of cultivation (1955), the above-mentioned correlations did not appear.

In the Carpathians, the percentage of clayey substances of the soil, varying from 6 per cent to 54 per cent, increased with altitude. The coefficient of regression of the clayey substances on altitude, indicating an increase of 1.56 per cent for each increase in altitude of 100 meters was significant at about the 1 per cent level.

Because of the above stated correlation it is difficult to say whether the observed decrease in yield in mountain conditions together with the increase in $K_2O$ content of potato tubers resulted only from the difference in the altitude or also from the varying contents of clayey substances in the soil.

*Potatoes transferred from Carpathians to the lowlands.*

After two and then three years of cultivation, potatoes were transferred from all the stations to the neighborhood of Cracow, where they

had identical conditions of soil and cultivation. Those from the various regions, which differed in geographical position and in elevation above sea level, could be differentiated quite easily on the basis of the production of top growth and of reserve materials stored in the tubers. This occurred in healthy plants as well as in ones affected with virus diseases.

Potatoes of the variety Epoka, derived from 32 experimental stations in the Carpathian mountains showed, when cultured near Cracow in 1957, a distinct increase in yield in comparison with the parent material from the mountains. Among the 32 experimental fields, 5 were situated higher than 1000 meters above sea level, 7 were between 800 and 1000 meters, 13 were between 600 and 800 meters, 5 were between 500 and 600, and 2 were between 400 and 500 meters above sea level. An increase of yield after transferring to the lowland occurred in 30 cases for both Epoka and Ackersegen and in 5 cases only in Epoka.

The average difference between the yield of the Epoka parent material from 32 fields in 1956 and the yield near Cracow in 1957 was 47.5 $\pm$ 3.6 g/plant. The tubers of healthy Epoka plants showed, in comparison with parent material, a decrease of $K_2O$ content in the tubers. The mean difference of $K_2O$ content in potato tubers cultivated in the mountains and after transfer to the lowland was 273 per cent, which was significant at the 1 per cent level (Table 1).

The mean difference between the single plant yield of the Ackersegen parent material in 1956 and that of the same lots grown near Cracow in 1957 was 17.86 $\pm$ 4.09 g/plant. The mean difference of $K_2O$ content of healthy potatoes cultivated in the mountains and after transfer to the lowlands was 365 per cent, which was significant at the 1 per cent level.

Dwarfness of potatoes and decrease in yield in the Carpathian mountains was correlated, as we have stated, with elevation above sea level and probably also with the content of clayey substances in the soils. It remains a question whether an increase in yield after transfer from the mountain to the lowland depends upon a change of climate or also of soil conditions.

The station in the neighborhood of Cracow, Gorka Narodowa, where all the potatoes from the described terrain were planted collectively in 1957, had fertile alluvial soil with clayey substances amounting to 8 per cent. Although many of the potatoes in the Carpathian experimental fields were planted in heavy soils with a higher percentage of clayey substances, they were also some, for example, located 560 to 700 meters above sea level, in the Dunajec Valley, where the experimental fields differed from one another fundamentally. Percentage of clayey substances in the soils varied from 0 (pure peat) to 15.7 per cent. The increase of yield after transferring to the neighborhood of Cracow was independent of the type of soil from which the potatoes came.

The same experiments were repeated in the year 1958 with similar results.

The most probable factor responsible for this phenomenon is temperature. Went (9) has shown that potato tubers produced on plants grown under low temperature, greenhouse conditions, produced more and heavier potatoes when used as seed than do those produced on plants grown at high temperatures.

The tubers of parent and grandparent generations in our experiments were produced in the mountains where the mean daily temperature from June to September ranged from 10° C. to 14.5° C. After transferring to Cracow the tuber formation took place at different temperature conditions when the mean daily temperature from June to September was about 15.8° C. Striking is the fact that simultanously with the increase of yield in Cracow the K content of the tubers decreased.

*Experiments carried out with potatoes from low lying mountain stations.*

In the Carpathian foothills, which descend toward the valley of the Vistula, 10 experimental fields were situated on gently inclined, open slopes, 300 to 400 meters above sea level. The soils were characterized by a relatively high content of clayey substances.

Pomeranian potatoes, under such favorable conditions of cultivation, gave high yield during two years. A decrease of yield occurred only in case of strong infection by viruses. On the other hand, after being transferred to the neighborhood of Crocow, they not only showed no increase in yield but in most cases there was a yield decrease even when free from disease. The K content in the tubers did not reveal such a regularity as it had in the mountain experiments described above. In some cases, after transfer to the neighborhood of Cracow, tubers had a higher percentage of K than the parent material.

As shown in Table 1 there was no difference in the mean daily temperature (June through September) between Carpathians foothills and neighborhood of Cracow.

*Incidence of virus diseases in potatoes transferred from the Carpathians to the lowlands.*

Under the Cracow conditions, characterized by strong invasions of aphids and location near fields affected with leaf roll and streak, the plants from tubers transferred from the high lying mountain experimental fields were distinguished during the first year of cultivation by their good state of health.

In the year 1956, the Epoka variety grown on experimental fields situated higher than 400 meters above sea level, showed 9.4 per cent virus infected plants, and variety Ackersegen 7 per cent. After transferring to Cracow in 1957, potatoes derived from the same lots, showed 26 per cent of virus infected plants in the variety Epoka and 25.3 per cent in Ackersegen.

On the other hand the Epoka variety grown in 1956 on fields situated below 400 meters above sea level showed about 28.6 per cent of virus infected plants, and Ackersegen 24.8 per cent. After transferring to Cracow, plants of the Epoka variety derived from these lots were 51.6 per cent virus infected and those of the Ackersegen variety 48.8 per cent. The potatoes derived from the Carpathian foothills were more susceptible to virus infection than were those from the high mountain stations.

## Summary

1. The transfer of potatoes from optimal maritime conditions (Pomerania) to the Carpathian mountain, 300-1200 meters above sea level,

resulted in a decrease in single plant yield, of 44 g for the variety Epoka and 59 g for the variety Ackersegen for each 100 meters increase in altitude.

2. A year to year increase of K in potato tubers planted in the Carpathians was found. Under our mountain conditions the content of K in potato tubers was correlated with a decrease in yield.

3. Transfer of potatoes from the mountains into the lowlands, irrespective of the kind of soil in which the plants had grown, caused a considerable increase in yield and a decrease of K in the tubers in the first year of cultivation. The most probable factor responsible for this phenomenon is temperature. The mean monthly temperature during the vegetative period decreases as elevation increases. The conditions under which parent and grandparent generations were grown affected the yield in the lowlands. When tubers produced at low temperatures in the mountains, were planted near Cracow, yield was increased, the K content of the tubers decreased, and there was little spread of leaf roll and streak.

4. Potatoes transferred from low lying mountain stations, below 400 meters above sea level, to the lowlands did not respond with increase in yield, nor did the K content in the tubers decrease. Also the plants were highly susceptible to streak and leaf roll.

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# TESTING POTATO SEEDLINGS FOR RESISTANCE TO THE LEAF ROLL VIRUS[1]

J. P. MACKINNON, D. F. RANKIN AND L. C. YOUNG

The leaf roll disease of potatoes was first reported in New Brunswick in 1915 (4) though it probably occurred much earlier. Since then the disease has appeared annually in varying severity. It reached epiphytotic proportions in 1936, and as a result of this increase, breeding for resistance to the leaf roll virus was introduced into Canada's National Potato Breeding Program, and the first crosses were made in 1937. Testing seedlings for resistance to the virus was begun in 1938 and with some modification of procedure has been continued ever since. We herewith describe the testing methods and give some results for the five-year period, 1955-1959.

## MATERIALS AND METHODS

The first seedlings tested for resistance to the leaf roll virus were derived from crosses of parental varieties that had previously shown some resistance. All the progenies resulting from these crosses were at first tested, but later only those seedlings that were selected on the basis of horticultural characteristics and which represented only a very small percentage of the original number, were entered in the tests.

During the years 1955 through 1959, tests were made in both greenhouse and field. Eight sets of each seedling were planted in the greenhouse in January on soil-filled benches with healthy plants of a susceptible variety interspaced among them to serve as controls. Green peach aphids, *Myzus persicae* (Sulz.), were reared on infected potato plants and used to transmit the virus. About 20 aphids were carefully placed on each seedling and control when the plants were two to six inches high. The plants were examined periodically for the next three days to assure that some aphids were feeding on each, and if they were not feeding, others were put on. The aphids were left to feed for 10 days and then killed by fumigation with nicotine. All seedlings with two or more plants showing virus symptoms during their growing period were discarded at harvest time. The remaining seedlings were selected for further tests the next year, one tuber being saved from each plant. The number of control plants that became infected served as a record of virus transmission for each season's test.

The field tests, from 1955 to 1958 inclusive, were conducted at two locations in the province about 30 miles apart. In 1959 the tests were made at only one location.

The general planting consisted of alternate rows of leaf-roll infected stocks with the intervening rows being planted to seedlings and varieties under test. Each plot consisted of a single row containing 10 sets which was not replicated. One plot in every six was planted with healthy sets of a known susceptible variety. This plot served as a control to determine the amount of natural spread of the virus during the season. The control

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plots were planted with healthy Green Mountain seed in 1955 and the same stock was replanted in 1956. In 1957 healthy Chippewa seed was planted in the control plots and this stock was replanted in 1958 and again in 1959. This change from Green Mountain to Chippewa as the control variety in both field and greenhouse tests was made because the former variety proved so susceptible to contamination with the mosaic-inciting viruses A and Y. Chippewa is equally susceptible to leaf roll (2, 5, 7, 9), but much more resistant to viruses A and Y (7, 8).

Early in the season the plots were sprayed with DDT to control damaging insects but during the remainder of the season they were sprayed with fungicides and calcium arsenate, which are nontoxic to aphids. Aphid populations were allowed to increase throughout the summer to allow natural spread of the virus. The seedlings were examined three times during the season and plants that showed disease symptoms were recorded. Seedlings were discarded or retained for further testing in a manner similar to that described for the greenhouse tests.

## Results and Discussion

From 1955 to 1959 inclusive, 132 seedlings were tested in the greenhouse and field. Of these, six had already survived two years of greenhouse testing and seven had survived one year. Also, six had been in the field for two years and eleven for one year without showing symptoms. In the greenhouse tests, 71% became infected in the first year, 20% the second year and all but one were eliminated during the third year. Seedling F 4896 remained free from infection after six consecutive years of testing. Eighty-three per cent of the Green Mountain plants were infected in 1955 and 94% in 1956. In 1957, 1958 and 1959, the percentages of Chippewa control plants that became infected were 100, 96 and 100 respectively. Tests were started on other seedlings in 1958 and 1959, however these have not been completed.

In the field trials 42% of the seedlings showed disease symptoms during the first year; 28% in the second year; 8% in the third year; and less than 5% in subsequent years. Tests are being continued on 19 seedlings that have been exposed only one, two or three years. Four seedlings failed to show symptoms after four years in the field. Virus infection in the Green Mountain controls was 21% in 1955 and reached 44% in 1956. The Chippewa showed 6% infection in 1957, 34% in 1958 and 85% in 1959.

The records of 10 of the most resistant seedlings tested are given in Table 1. Seedling F 4896 appears to possess a high degree of resistance to aphid inoculation as it has remained free from infection after six consecutive years of testing in the greenhouse. However, it is not immune to the virus as it has been artificially infected by grafting.

Other seedlings have shown lesser degrees of resistance. Seedlings F 4864 and F 4871 remained healthy in greenhouse and field tests in 1953 and 1954 but became infected in 1955. Seedlings F 4872 and F 4886 remained healthy in greenhouse and field trials in 1953 and 1954. Both became infected in greenhouse trials in 1955 but remained healthy in field trials for two additional years 1955 and 1956, after which their testing was discontinued. Seedling F 4768 showed symptoms during

TABLE 1.—*Reactions of potato seedlings in the greenhouse and field when exposed to aphids carrying the leaf roll virus, 1955 to 1959 inclusive.*

| Parentage | Seedling or variety | Greenhouse reaction | | | | | Field reaction | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1955 | 1956 | 1957 | 1958 | 1959 | 1955 | 1956 | 1957 | 1958 | 1959 |
| Imperia x Katahdin | F4864[1] | +[3] | | | | | + | | | | |
| Imperia x Katahdin | F4871[1] | + | | | | | + | | | | |
| Imperia x Katahdin | F4872[1] | + | | | | | — | — | | | |
| Imperia x Katahdin | F4886[1] | + | | | | | — | — | | | |
| Southesk x Katahdin | F4896[1] | —[4] | — | — | — | | — | — | | | |
| Green Mountain x Menominee | F4768[2] | + | | | | | — | — | — | — | + |
| 96-56 (USDA) x Katahdin | F5025[2] | — | + | | | | — | — | — | + | |
| 927-3 (USDA) x K12.42-5 Krantz | 2953-1 | | W[5] | W | | | | | — | — | — |
| 927-3 (USDA) x K12.42-5 Krantz | 2953-10 | | W | + | | | | | — | — | — |
| 927-3 (USDA) x K12.42-5 Krantz | 2953-14 | | — | + | | | | | — | — | — |
| | Green Mountain | + | + | | | | + | + | | | |
| | Chippewa | | | + | + | + | | | + | + | + |

[1]Seedling remained healthy in greenhouse and field tests in 1953 and 1954.
[2]Seedling remained healthy in greenhouse test in 1954.
[3]+ = Seedling infected.
[4]— = Seedling healthy.
[5]W = Seedling wilted.

the second year of greenhouse testing, but remained healthy until the fifth year in the field trials. Seedling F 5025 remained healthy until the third year of the greenhouse tests and the fourth year of the field trials. Seedlings 2953-1 and 2953-10 showed no symptoms during three years of field testing but both displayed wilting symptoms in the first year of the greenhouse test. Tubers from wilted plants of 2953-1 were grown in the greenhouse and again produced plants that wilted, but similar tubers from 2953-10 gave rise to plants showing typical leaf roll symptoms. Virus was transmitted from wilted plants of both these seedlings by aphids to *Physalis floridana* Rydb.

Wilting is an unusual leaf roll symptom displayed by infected seedlings of U.S.D.A. 927-3 at high temperatures (27° C.) (10). As the 2953 series of seedlings was derived from crosses made with U.S.D.A. 927-3, it appears probable that the wilting characteristic is of a genetic nature, and has been inherited by some of the progeny. Several other seedlings from this cross, and other crosses, in which one parent was U.S.D.A. 927-3 similarly wilted when infected.

Immunity to leaf roll apparently does not exist in the material tested, but the greenhouse tests herein described were much more favorable for virus spread than would normally exist under natural field conditions. A high degree of resistance to aphid inoculation has been demonstrated in seedling F 4896. Our results also show that resistance can be found in seedlings selected first for desirable horticultural characteristics.

Factors involved in resistance to leaf roll are apparently of a complex nature. Varieties show marked differences in suitability for development and reproduction of the main vector, *M. persicae* (1), but these differences alone do not account for resistance. The Katahdin variety has been frequently reported to be resistant to the leaf roll virus (2, 3, 5, 7), yet it often supports large populations of *M. persicae* (1, 6). Also, the variety Russet Burbank has been reported to be very susceptible to leaf roll (5), yet it has been classified as an unfavorable host for the vector (6). Anatomical differences among varieties and seedlings are most likely responsible for the efficiency by which viruliferous aphids can infect healthy plants.

The breeding and testing of seedlings for more than 20 years have not produced a leaf roll resistant seedling of sufficient horticultural quality to be released as a named variety, but progress in this direction has been made. Until more knowledge is gained on the nature of such resistance, progress will be slow, but acceptable varieties should eventually result that will reduce severe losses caused by this virus.

## Summary

Data on exposure of potato seedlings to natural infection by the leaf roll virus in the field and artificial inoculation by aphids in the greenhouse from 1955 to 1959 inclusive show that seedling F 4896 is the most resistant of the 132 seedlings tested. Most seedlings were eliminated in the greenhouse tests the first year but several remained healthy in the field for four years. No seedlings have been found immune to the virus but resistance to aphid inoculation has been demonstrated. Recombination of these characters in a breeding program should eventually produce an acceptable variety highly resistant to leaf roll.

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# EFFECT OF FOLIAR APPLICATIONS OF CHLORIDE AND SULFATE ON THE SPECIFIC GRAVITY OF WHITE POTATO TUBERS[1]

H. W. GAUSMAN, G. O. ESTES, AND R. A. STRUCHTEMEYER[2]

This note summarizes results of a pilot study to test the premise that foliar-applied chloride (Cl—) and sulfate ($SO_4$=) had a differential effect on the specific gravity of white potato tubers.

## MATERIALS AND METHODS

Three foliar applications of solutions of sodium chloride (NaCl) and sodium sulfate ($Na_2SO_4$) were made at weekly intervals to Katahdin potato plants which were fertilized at the time of planting with 2000 pounds per acre of an 8-12-12 fertilizer with 2% MgO. The first foliar application was made at bloom stage and the remaining two foliar applications were made at weekly intervals thereafter. Appropriate quantities of NaCl and $Na_2SO_4$ were used in the sprays to give equal amounts by weight of $Cl^-$ and $SO_4$=; namely 150, 300, and 600 ppm solutions which were compared with a water spray as a control. A combination of 300 ppm $Cl^-$ with 300 ppm $SO_4$= was also used as a foliar spray. Assuming a complete vegetative canopy, the total rates of application in pounds per acre of both $Cl^-$ and $SO_4$= were: (a) 0.98 pounds for the 150 ppm spray, (b) 1.96 pounds for the 300 ppm spray, and (c) 3.93 pounds for the 600 ppm spray. At the time a top killer would normally be used, ten plants were harvested from each treatment for making specific gravity determinations on the tubers. These plants were previously selected at the time of treatment on the basis of uniformity in size and equality in time of blooming.

## RESULTS AND DISCUSSION

The results are presented graphically in Fig. 1. Duncan's multiple range test (2) indicates that foliar applications of $SO_4$=, excepting the 150 ppm level, and the combination spray of $Cl^-$ with $SO_4$= significantly decreased the specific gravity of potato tubers compared with applications of $Cl^-$ at levels of 0, 150, and 300 ppm. This effect seems to be independent of differences in chemical equivalency between rates of $Cl^-$ and $SO_4$=, since a total of approximately 18,500 and 37,000 milliequivalents of $SO_4$= applied from respective solutions of 300 and 600 ppm of $SO_4$= decreased the specific gravity of tubers compared with a total of about 25,000 milliequivalents of $Cl^-$ obtained from the 300 ppm solution of $Cl^-$. In addition, the carrier (sodium) of $Cl^-$ and $SO_4$= apparently had little, if any effect, on the specific gravity, since an approximate 40% difference in sodium content obtained by comparing D with G or B with E, Fig. 1, was not associated with a significant difference in specific gravity.

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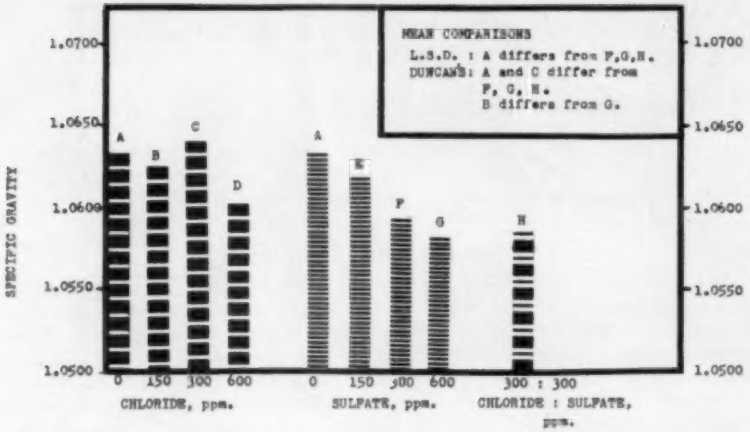


FIG. 1.—Effects of foliar applied chloride and sulfate on the specific gravity of Katahdin potato tubers.

The results seem especially significant when consideration is given to amounts of anions applied in pounds per acre. Applications of 1.96 or 3.93 pounds per acre of $SO_4^=$ caused decreases in specific gravity which were of statistical and practical significance.

The results suggest that contents of $SO_4^=$ and $Cl^-$ in the atmosphere might be more important in the nutrition of potato plants than has been previously thought possible. For example, estimates of amounts of chloride added per acre in rainfall, vary from five to several thousand pounds per acre per year, and Estes has found that 24 pounds of sulfur per acre is absorbed annually from the atmosphere in Central Maine (1, 3).

## CONCLUSION

It is concluded that foliar applied anions of chloride and sulfate may have a differential effect on the specific gravity of potato tubers. Serious attention may have to be given to amounts of chloride and sulfate added from the atmosphere in rainfall before factors affecting specific gravity can be more correctly defined.

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# GREENING AND SOLANINE DEVELOPMENT OF WHITE POTATO IN FLUORESCENT LIGHT[1]

ARNE LILJEMARK[2] AND ERIC WIDOFF[3]

## INTRODUCTION

The work to be described began in 1954 when the practice of retailing white potatoes in consumer bags was rapidly growing in Sweden. The bags were made of paper of varying quality and with different light protecting abilities. Furthermore, it was expected that transparent material would be used for inspection windows in the paper bags or for the entire packages. It was feared that complaints about greening and bitter taste in potatoes as a result of this would be more common than before. Therefore, a study was started in an attempt to get the following questions answered:

1) Could potatoes be kept visible by some type of illumination during display without turning green and bitter?

2) How much greening and solanine development would be induced in potato tubers by varying exposure to defined light sources?

The study was limited to the retailing part of the potato distribution chain.

## LITERATURE

After illuminating potato tubers in different consumer packages, other authors (8, 10, 16) have reported that tubers greened approximately in proportion to their visibility in the packages. When the greening was not too severe, off-flavor was noticeable in tubers if boiled unpeeled, but not significantly so if they were peeled before boiling. Greening was judged as objectionable in tubers in transparent bags which had been kept for more than three days in light corresponding to strong shop illumination. According to another source (1), ambercolored polyethylene could protect the tubers against light without appreciably diminishing their visibility, so they could be kept 6-10 days in a retail shop.

Chlorophyll development in potato tubers has been investigated by Larsen (13) who also tried to protect tubers against daylight with common cellulose-film of different colors. The red, green and blue films gave about the same reduction in foot-candles measured by a photo-cell, but the amount of chlorophyll was less in green and in blue light, than in red light. Yellow film gave smaller reduction in foot-candle-readings and in chlorophyll development.

Earlier, Conner (5) studied the solanine formation in tubers in light of different wave-lengths and estimated the degree of greening. He summarized that wave-lengths, effective for glucose-synthesis caused greening but did not significantly promote formation of solanine, and that ultraviolet light of approximately 3000 A was effective for development of solanine but not for greening.

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Results from more recent work on effects of illumination on potato tubers (7) showed, that the difference in chlorophyll developing effect of different light intensities was much greater between 25 and 50 foot-candles than between 50 and 75 resp. 100 f. c. of light from fluorescent lamps. During 60 hours of illumination with 75 f. c. the chlorophyll development was not affected by enclosing the tubers in bags of red, blue, yellow or uncolored polyethylene, although the colored films could reduce the light intensity to approximately 50 f. c. During 96 hours of illumination there was no significant difference in greening effect between continuous lighting and alternating 12-hour periods of light and darkness. In organoleptic tests the investigators were not able to distinguish between potatoes greened for 14 days at 75 f. c. and non-greened potatoes.

Severe greening is not always accompanied by high solanine formation because of potato variety factors and other factors which modify the light-influence (14, 15). Studies on the influence of climate and cultivation practices, etc. have been made (9, 11, 17, 19), but not very much has yet been revealed about such causes of variation.

## Experimental Work and Results

When the literature was studied in 1954, there seemed to be a chance to get a lower induction of chlorophyll formation by light in the wave-length range 5000-6000 A, where both the absorption curves of chlorophyll a and b and photosynthesis are low and the sensitivity of the human eye is highest. It was hoped that solanine formation also should be low in that range—if not, it could be worth-while to try red light to allow chlorophyll development and hope for less solanine formation in that range.

A great part of the work had to be devoted to the analytical methods. The main results are here presented in two groups, light-color and light intensity.

### A. Materials and Methods

*Illumination facilities:*

In a cellar room with 80-90% relative humidity and a normal temperature around 18° C light-tight illumination cabinets were arranged on tables, with a holder for 40 W fluorescent tube lamps within each cabinet.

After a preliminary experiment with bare fluorescent lamps giving light of the colors daylight type, blue, green and red (Philips TL 40 W No. 55, 18, 17 and 15), photographic filters were applied to limit the spectral distribution of the blue and green lights (Ilford filters No. 306 and 408). Therefore the spectral energy distributions of Fig. 1 were obtained within the following approximate wave-length ranges: daylight type 3500-7500 A, blue 4000-5000 A, green 5000-6000 A and red 6000-7000 A.

In the first series with "filtered" light the height of the lamp holders was adjusted until a photographic exposure meter gave the same value at the table in each cabinet. In the following series the lamp holders were adjusted to give a closer agreement between the cabinets in irradition energy at the table. That was accomplished by means of an available lux-meter with the same wave length sensitivity as the human eye. It was calculated that to obtain approximately the same physical irradiation intensities at the table below the used light sources, the physiologically

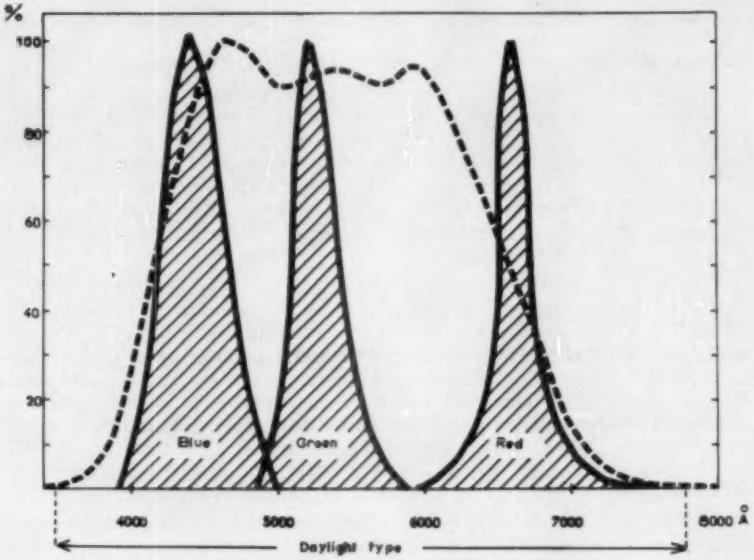


FIG. 1.—Spectral energy distribution of light sources.

calibrated luxmeter should give the relative values 100:5.9:176:19.4 for daylight type, blue, green and red light, respectively. When the previously used illuminations, adjusted to the same exposure meter readings were checked with the luxmeter, the relative lux values were 100:13.3:133:33.4, which showed that the blue and red irradiations had then been stronger in relation to daylight and green light.

Because of its low light emission, the blue light source became decisive for the practical upper limit of irradiation intensities.

*Tubers and sample preparation.*

The potatoes were stored in the dark at 5 or 10° C between harvesting and illumination experiments. Immediately before exposure the tubers were washed and inspected. If visibly green or with other defects they were rejected. The tubers were placed on the illumination tables within areas with even illuminations and marked with ink on the side facing the table. Twenty tubers were removed for each analysis.

From the illuminated surface (opposite the ink-mark) of each tuber 4-6 discs with 10-15 mm diameter and 3 mm thickness were cut out with special tools. The "eyes" were avoided. The discs from twenty tubers were homogenized in a high speed blender and analyzed in duplicates.

Discs were taken from the outer layers only, in order to get high concentration of solanine in the sample to analyze, with reference to the statements about solanine distribution in potato plant made by Lampitt et al (12). The thickness of the discs was determined according to Larsen (13) who showed that chlorophyll is not found deeper than 3 mm from the surface of the tuber.

In some final instances 20 whole tubers were homogenized for analysis.

*Chlorophyll analysis.*

Chlorophyll was prepared from exposed tubers by extraction with 85% acetone and purification in ether (2). The mixture of chlorophyll a and b was measured in a Beckman B spectrophotometer at 6425 A and 6600 A. The amounts of chlorophyll components were calculated according to Comar et al, (4), giving the approximate proportions 2a to 1b. The calibrating curve for the total chlorophyll content of the acetone extract was obtained by measuring at 6000 A, where the absorption curves of chlorophyll a and b intersect.

In the homogenized discs of potato tubers, the total content of chlorophyll was then determined according to a slightly modified AOAC-method. About 5 g of the sample was weighed in a mortar with 0.1 g of sodium carbonate and was extracted with 85% acetone, which was added successively during grinding with burned sea sand. The extract was decanted through filter and the chlorophyll content was determined by measurement in a spectrophotometer. During the entire analysis the sample was protected against light as adequately as possible.

*Solanine analysis.*

Solanine here stands for solanine and solanidine. From potato sprouts solanine was prepared by a combination of the methods used by Dabbs et al. (6) and Rooke et al. (18). Solanine was extracted with acetic acid and precipitated with ammonia. The precipitate was purified by repeated dissolution in acetic acid, precipitation with ammonia and extraction of the precipitate with ethyl- and amyl-alcohol. The melting point of the substance obtained was about 235° C. To make up a calibrating curve different amounts of solanine were dissolved in 0.5% acetic acid. Concentrated sulphuric acid and formaldehyde were added to give a red-violet color and the solutions were measured at 5250 A (18).

The analytical method was later modified according to Baker et al. (3). The finally adopted procedure was as follows: From the homogenized sample 15 g were weighed in a Soxhlet-thimble and extracted for 20 hours on sand bath with about 120 ml 96% ethanol, acidified by 3 ml glacial acetic acid. The extract was concentrated by evaporation to 1-2 ml and 5 ml 5% sulphuric acid were added. The suspension was transferred through a rather soft paper filter into a centrifuge tube. The extraction vessel was washed with another 5 ml-portion of 5% sulphuric acid. To the filtrate concentrated ammonia was dropwise added (up to pH 9, 4) to precipitate solanine. The centrifuge tube was heated in a 80° water bath and allowed to stand over night at +3°C. Next day the sample was centrifuged and decanted. The precipitate was washed with 10 ml 1% ammonia. The sample was centrifuged again and decanted. The precipitate was dissolved in 10 ml 1% sulphuric acid and undissolved substances were centrifuged down. To 3 ml of the solution 6 ml of concentrated sulphuric acid were added dropwise during 3 min. in ice-water bath and, about 1 minute later, 3 ml of a 1% solution of formaldehyde were added dropwise. When the solution had been standing for 90 minutes at room temperature, the absorption at 5250 A was measured (18).

## B. Light Color

1. In the summer of 1954 three lots of early crop potato (Eva variety) from different farms were illuminated with fluorescent lamps giving blue, green, red, and daylight type of light. The height of the light sources was regulated according to their total light emission as specified by the manufacturer to give approximately the same illumination (about 200 lux) at the table. During 10 days of exposure the chlorophyll content rose to about three times the starting level in red and green light. In blue light it rose about five times and nearly as much in daylight type. The blue light source, however, had a very wide spectral distribution, covering the green area and overlapping into the red. The green light overlapped at both ends into the blue and red areas.

The solanine values were irregular, so the analytical technique had to be adjusted. .

2. When filters had been applied to the blue and green lamps to cut off the ends of their spectra, potatoes of three varieties (Bintje, King Edward VII, Majestic) were illuminated during the period December 1954 to February 1955. The light intensities at the table were adjusted to the same reading on an exposure meter for photography, corresponding to about 65 lux below the daylight lamp.

The potatoes were exposed for 4, 10, and 20 days. As the illumination cabinets were rather small, the tubers were exposed in a batch-wise manner. Samples from the three varieties were exposed for four days, then were replaced by new samples which were exposed for ten days, etc.

The rate of chlorophyll development was most rapid in King Edward, a little slower in Majestic and slow in Bintje, which had a thicker skin (Fig. 2). The light colors gave clearly different amounts of greening in King Edward in the final order red, daylight, blue and green. Also in Majestic red light developed most chlorophyll but the responses of the other illuminations could not be clearly distinguished from each other.

The method for solanine analysis had been greatly revised, but the recovery was not yet as good as in later series. In the outer layers of the tubers, Majestic had the highest solanine content after exposure to the daylight lamp and King Edward (red spotted skin) after exposure to red light, but otherwise no clear differences in solanine development could be found between the light colors. Taste testing of boiled tubers after four days' exposure confirmed, however, in part the solanine values, in that King Edward from daylight and Majestic from red light were acceptable, whereas King Edward from red light and Majestic from daylight had the most pronounced off-flavor.

Because of the relatively high amounts of both chlorophyll and solanine in Majestic tubers, this variety was chosen for further tests.

3. In the next illumination period the light intensities were adjusted to approximately the same physical level, corresponding to the illumination 150 lux under the daylight lamp, as described in the method section. Compared with the state after this final adjustment, the blue and red illuminations in the previous series had been somewhat too strong in relation to the other illuminations.

Majestic tubers were exposed during 15-18 days in two series. In

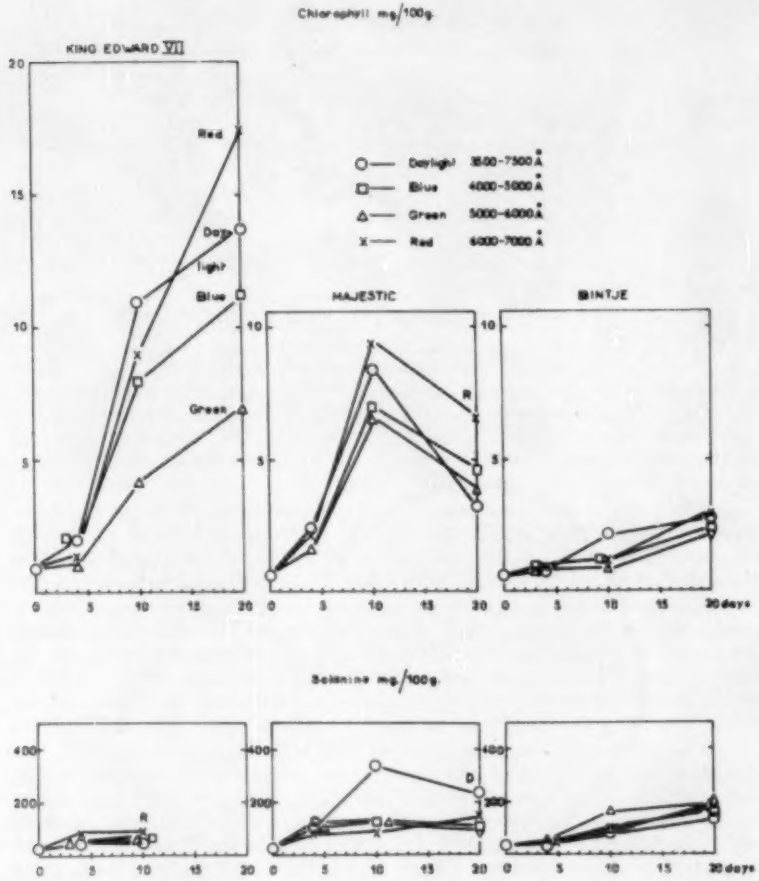


FIG. 2.—Chlorophyll and solanine (dry weight basis) in the 3 mm deep surface layer of potato tubers exposed to light of different colours. The illumination was adjusted to the same reading on an exposure meter, corresponding to 65 lux in daylight type of light. (Dec. 1954 - Feb. 1955)

both series the different illuminations induced chlorophyll formation in the following order (Fig. 3, a and c): daylight lamp (high), red and blue light (middle) and green light (low). The level was only slightly lower in the second series, where the temperature was lower because of reasons beyond control.

In the first series, daylight induced higher solanine content than red light, with the other light colors in between, but the level was about the same during the whole exposure time. Taste testing after 3 and 10 days'

exposure revealed a clear distinction between tubers exposed to daylight type, colored light and unexposed tubers. The disagreement was thought to be due to the beginning sprout development, as it was late in the season (March). Solanine, formed in the outer layers of the tubers, could possibly be transported through the vascular tissue to the buds which were not included, when discs for analysis were cut. This suggestion was confirmed by the fact that the solanine content of *whole* tubers after 8 days of exposure was of the same order as that of the 3 mm thick outer layer of tubers from the same sample, (Fig. 3 a). Therefore, a second seriec was started already in December the next season, but as shown in Fig. 3 c, the results turned out about the same as in the March series.

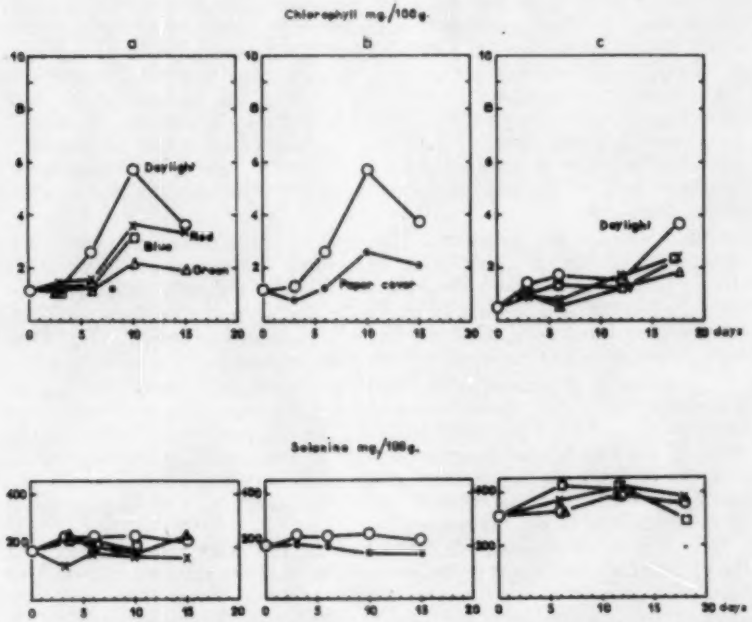


FIG. 3.—Chlorophyll and solanine (dry weight basis) in the 3 mm deep surface layer of Majestic tubers exposed to light of different colours. The irradiation was adjusted to approximately the same energy level, corresponding to the illumination 150 lux in the daylight type of light, as described in the text. a. March 1956. The filled circles after 8 day's exposure correspond to analyses made on whole tubers from the daylight lamp. 18°C. b. March 1956. Exposure to daylight lamp, uncovered (circles) or covered with brown paper (dots). 18°C. c. Dec. 1956. 12 - 14°C.

## C. LIGHT INTENSITIES

*Paper cover.*

1. In the first two series, beside the direct exposure to daylight lamp, tubers were covered with white paper from paper bags, which were

used at that time for potatoes in some retail stores, and exposed to the same light. The paper transmitted about 30% of the visible light, more in the red than in the blue end of the spectrum. At 200 lux the chlorophyll, developed in early crop potatoes (Eva) covered by white paper, amounted to about 70% of that developed in uncovered tubers.

At 65 lux the chlorophyll formation in tubers covered with white paper, also was about 70% of that in uncovered tubers (King Edward and Bintje) or nearly the same as that in uncovered tubers (Majestic). The solanine content of test-discs from covered and uncovered tubers was exactly the same for King Edward and Majestic. Test discs from covered tubers of the Bintje variety contained even more solanine than those from uncovered tubers.

In the third series brown paper from commonly used special purpose potato bags (2 kg) was used as cover. The brown paper transmitted about 8% of the visible light and did not favor transmittance of red light as much as the white paper used earlier. The chlorophyll formation in paper covered tubers was appreciably lower when exposed to daylight lamp than that in uncovered tubers and nearly the same as the chlorophyll formation in green light (Fig. 3 b). The solanine content of test-discs was slightly lower in covered than in uncovered tubers but remained at approximately the starting level during the entire irradiation time as mentioned previously.

2. Majestic tubers were illuminated at 150-300-600 lux from daylight lamp in April 1956. After two and four days no appreciable chlorophyll formation was obtained at 150 lux, and only small amounts developed at 300 and 600 lux (Fig. 4 a). After six and nine days, however, the greening was strong at all intensities. The solanine content of test discs from exposed tubers remained at the starting level.

3. The next season Majestic tubers were illuminated already in November to avoid disturbances caused by sprouting. Illuminations between 25 and 3600 lux were applied. The chlorophyll formation at 150 and 600 lux corresponded approximately to the results of the last series, whereas at 3600 lux much more chlorophyll was formed and at 25 lux less (Fig. 4 b). The chlorophyll content appeared to rise in proportion to the logarithm of the lux values.

In this series the solanine content of the test discs rose in analogy to the chlorophyll development despite the fact that the solanine content had been high already at the onset of the illumination. After three and four days of illumination taste tests were performed. Tubers exposed to 25 and 150 lux were then relatively alike and better than tubers exposed to 600 and 3600 lux.

4. For the next illumination series tubers of the Arran Consul variety were used, as they happened to be readily available at the laboratory. They contained about half as much solanine as Majestic tubers in their outer layers according to a previous check.

Tubers of the same size and shape were exposed to 150-200-600 lux. Analyses were made on a homogeneous mixture of twenty whole tubers.

There was a slight lag, which later disappeared, in the chlorophyll formation at 600 lux, but otherwise chlorophyll developed at a steady rate during the exposure time, as had been the case in most of the previous

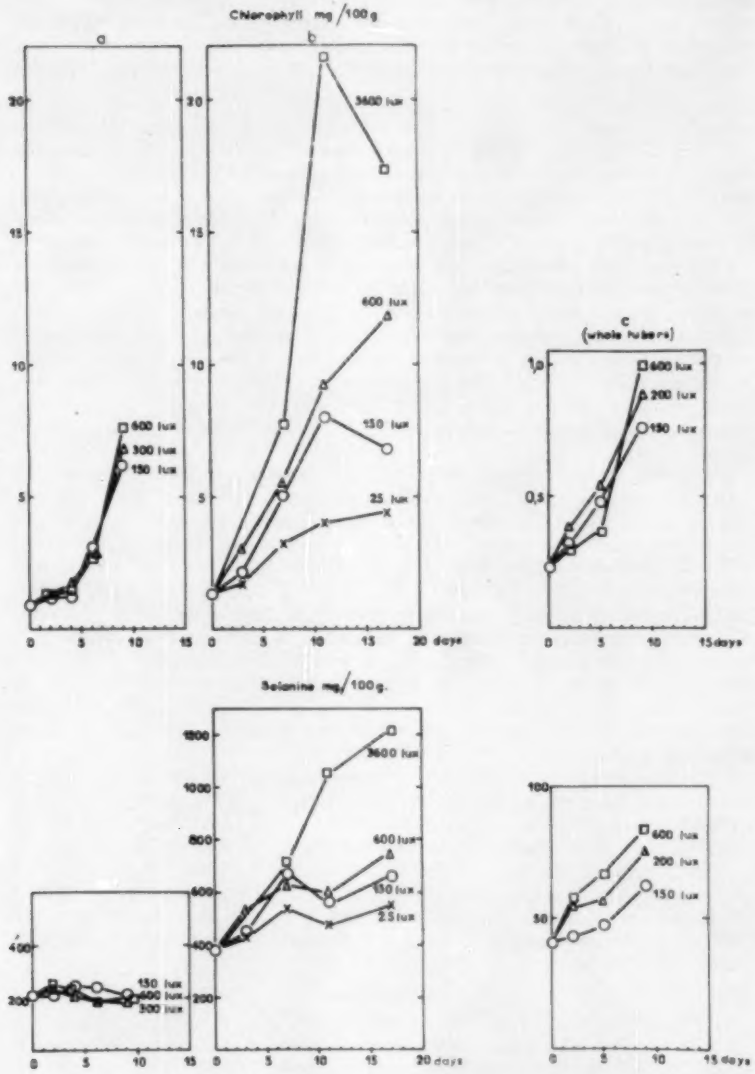


FIG. 4.—Chlorophyll and solanine (dry weight basis) in the 3 mm deep surface layer of Majestic tuber (a and b) and in whole tubers of Arran Consul (c) exposed to different light intensities (daylight lamp). a. April 1956. b. Nov. 1956. c. Feb. 1957.

series. But this time also the solanine analyses, when pertaining to whole tubers, gave values which were directly related to the exposure time and light intensity but at a lower level than previously obtained for discs from the outer layer of the tubers (Fig. 4 c).

## Conclusions

The effect of fluorescent light on formation of chlorophyll and solanine in potato tubers has been studied. Consideration has been given to different wave-lengths and different intensities

The chlorophyll and solanine content was determined colorimetrically in homogenized discs of 3 mm thickness from the illuminated surface of the tubers. This method of sampling tuber material was satisfactory for chlorophyll determination but failed on several occasions to give higher solanine content after exposure of the tubers, though off-flavor was induced. Possibly, solanine formed in the outer layers of the tuber could be transported through the vascular tissue to the buds and so be missed in sampling the material. This suggestion was confirmed by later analyses, made on whole tubers, showing that both chlorophyll and solanine developed at steady rates in tubers exposed to fluorescent light of daylight type.

Among some tested varieties Majestic was chosen as one apparently rather sensitive to light with respect to both chlorophyll and solanine. During exposure to fluorescent light within different wave-length ranges but of the same irradiation intensity (corresponding to the illumination 150 lux in daylight) the least chlorophyll formation was induced in the tubers by green light (5000-6000 A), more by blue and red light (4000-5000 A and 6000-7000 A resp.) and most by daylight type (3500-7500 A).

The chlorophyll content after a few days' exposure to green light was not higher than in tubers exposed to the same intensity of the daylight type fluorescent light and protected with brown paper from 2 kg potato bags. By reasons already mentioned the solanine values were not representative for the whole tubers, but taste tests suggested the same order.

It thus ought to be possible to keep potatoes visible in green light for at least as long a time as in brown paper bags in ordinary light without severe greening; a practical difficulty might be to keep strict wave-length limits. Also, it may prove psychologically unwise to display green-looking potatoes. Because of the high sensitivity of the human eye for green light, good visibility could be obtained in fairly weak light. According to results from irradiation trials with daylight type fluorescent light the irradiation intensity ought to be less than that corresponding to the illumination of 25 lux.

## Summary

Potato tubers were exposed to fluorescent light of the same irradiation intensity within the wave-length ranges 3500-7500 A (daylight type), 4000-5000 A (blue), 5000-6000 A (green) and 6000-7000 A (red). Green light induced the least chlorophyll formation in the outer 3 mm layers of the exposed tubers. The same amount of chlorophyll was induced by fluorescent light of daylight type through brown paper bags. Solanine determinations of the outer layers of the tubers gave irregular results,

and analyses ought to be made on whole tubers, as shown at the end of the study.

The effect of illumination intensities between 25 and 3600 lux of daylight fluorescent light was also studied.

## Acknowledgments

The investigation has been aided by grants from the Research Council of Agriculture.

Among those who have given valuable technical assistance in performing the analyses, the authors' particular thanks are due to Mrs. Marga Lindeberg.

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## NEWS AND REVIEWS

President Paul Eastman and recipients of Honorary Life Memberships, Russell Larson, Ben Picha, and Ora Smith, respectively.

### DR. ORA SMITH, HONORED

It gives me a great deal of satisfaction to present the name of Dr. Ora Smith to the Potato Association of America for Hororary Life Membership. In Presenting his name I would like to give a brief resume of his background. In the time allotted only a portion of Dr. Smith's background and career highlights can be covered.

Dr. Smith was born in southern Illinois. When not in school his time was spent on a vegetable farm. He specialized in vegetable production at the University of Illinois and received a Bachelor of Science degree in 1923. In 1924 he received a Master of Science degree at Iowa State College, and remained on the staff there. He went to California as a research assistant in 1927 and received his PhD in 1929, doing research with potatoes. In 1929-1930 he was on the staff at Oklahoma A. & M. College. In 1930 he went to Cornell as Assistant Professor in Vegetable Crops and became a full Professor in 1938. He is still at Cornell engaged largely in research on production, storage, and processing of potatoes with special attention to potato quality. He also teaches a course on potato production and processing.

Since going to Cornell Dr. Smith has had many other responsibilities. For several months in 1934 he was on leave to the Production Credit Division of the Farm Credit Administration. During a sabbatical year in

1938 he visited 75 colleges and experiment stations in 18 European countries, and studied their research programs. He is probably better known by potato people outside the United States than any other man from this country.

During the war he conducted several research programs on dehydration for the Quartermaster Corp. for which he was cited. In 1946 and 1947 he was a member of the staff of the Inter-American Institute of Agriculture and Science in Turialba, Costa Rica. In 1949 and 1950, on an eight months leave from Cornell, he inaugurated the Research Division of the Potato Chip Institute International and served as its first Director of Research, and still serves in that capacity. At the request of the Ministry of Agriculture of the Netherlands, he was sent to that country to study and help their potato industry in 1952.

Dr. Smith is affiliated with many honorary and scientific societies. He was president of the Potato Association of America in 1938-39 and secretary for four years. He has written over 250 scientific and popular articles. He recently co-authored a book on potato processing which will definitely be on the shelf of anyone interested in the potato. He was recently awarded a plaque and cited for his outstanding service to the potato industry by the National Potato Council.

To back-track a minute, in 1927 Dr. Smith married Laura Lee, while at Iowa State. They have two children, James, a graduate student in chemistry at Iowa State University and Sarah Jane, a senior at Ithaca High School. Mrs. Smith received her PhD at the University of California in 1930 and is presently on the staff of the Cornell School of Hotel Administration.

Dr. Smith's influence on potato research has been far more reaching than the highlights just mentioned indicate. To bear this out, at a recent Potato Utilization Conference four invitational speakers, during one half day session were former graduate students of his.

As one of his former graduate students and a fellow staff member, it is a very satisfying experience for me to present Dr. Smith's name to the Potato Association of America for Honorary Life Membership.

RICHARD L. SAWYER

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## MR. BEN PICHA, HONORED

It is a very great privelege today for me to present my very good friend, Mr. Ben Picha, as a candidate for Honorary Life Membership in The Potato Association of America.

Mr. Picha was born on a farm near New Prague, Minnesota in 1893. After graduation from high school, he attended the University of Minnesota. In 1916 he received his Bachelor of Science degree in Agriculture from that institution and he immediately enrolled in the graduate school. Before completing his Master's degree, he accepted a position to teach General Science at the Barton Academy in Mobile, Alabama.

Probably his first experience with potatoes came when he operated the Red River Seed Company at Moorhead, Minnesota, an organization dealing primarily with certified seed potatoes.

After seven years in the Red River Valley, he moved to southern Minnesota where he managed the Hollandale Marketing Association located on a newly developed area of peat land. It was here that Mr. Picha became intensely interested in the need for scab resistant varieties. While at Hollandale he made several hundred crosses in the search for better varieties of potatoes. He exchanged materials with Dr. Krantz of Minnesota, Drs. Schall and Irwin of Iowa, Professor Edmonson of Greely, Colorado and Dr. Stevenson of the United States Department of Agriculture. He also conducted extensive variety trials and cooperated with the National Potato Breeding Program.

In 1945 he moved to Grand Forks, North Dakota where he engaged in the business of growing and shipping certified seed potatoes. In order to expand his program of potato improvement he moved this work to an isolated area at Oklee, Minnesota. This provided him with a place to increase varieties and new selections and maintain them free of virus diseases. Today Mr. Picha has about six acres of first generation seedlings, promising selections, and new varieties. Many of these are still free of virus X.

He has cooperated freely with potato workers throughout the United States and Canada. True seed of many of his crosses have been grown by breeders in various Experiment Stations. As a result of his program in 1952 he introduced one of the first red varieties showing tolerance to common scab. This he called Redkote for its intense red color and smooth shallow-eyed tubers. At these meetings he will report on the introduction of his second variety — Erlired which shows extreme earliness, high red color and uniform tuber size and shape. From tests conducted in many states this variety appears to have a definite place in the early red potato producing areas. He also has several other promising selections which he intends to name and introduce in the near future.

During the past 15 years, Mr. Picha has been a member of the Minnesota Certified Seed Potato Commission and since 1955 he has been a member of the Potato Advisory Committee on research and marketing for the United States Department of Agriculture. He is a long time member of the Potato Association of America. He has travelled widely and is well informed on potato production and marketing problems. Mr. Picha could also be classed as a taxonomist, bacteriologist, meteriologist and chemist as many of his friends will agree.

Mr. President and members of the Potato Association of America, it is with a great deal of pleasure that I present to you Mr. Ben Picha of Grand Forks, North Dakota and congratuate him on his election to Honorary Life Membership in the Potato Association of America.

ORRIN C. TURNQUIST

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## DR. RUSSELL H. LARSON, HONORED

It is a privelege and an honor to present Dr. Russell Harold Larson for honorary life membership in the Potato Association of America. He has served the entire potato industry through his research on potato diseases since 1935. Since making his first contribution to potato pathology

on the common scab disease, Dr. Larson's work has delt with Verticillium wilt, internal heat necrosis, and a large number of virus diseases which include virus X, virus Y, virus M, virus S, virus F, virus A, leaf roll, potato yellow dwarf, and the soil borne corky ringspot virus. Resistance to viruses Y, S, and F have been reported from his laboratory. He has served the Potato Association of America meritoriously by his activities at the meetings in presenting research contributions and by his outstanding work as chairman of International Relations Committee.

Dr. Larson was born on November 5, 1904, at Wausau, Wisconsin, the son of William Lars and Josephine P. Larson.

Dr. Larson earned the Bachelor of Philosophy degree from Ripon College, 1928, the Master of Science degree from the University of Wisconsin in 1930, and the Doctor of Philosophy degree from the University of Wisconsin in 1934. Since obtaining his PhD Dr. Larson has been working at the University of Wisconsin. In 1945, he became pathologist with the United States Department of Agriculture and assistant professor at the University of Wisconsin. In 1958, he ws promoted to associate professor at the same university.

Dr. Larson studied plant virus research in England, Ireland and Scotland for three months in 1946, and in 1954 he accepted a Fulbright Fellowship for six months of study in Holland on plant virus research. Societies to which Dr. Larson belongs are: Phi Sigma, Gamma Alpha, Sigma Xi, The American Phytopathological Society, and the Potato Association of America.

During Dr. Larson's productive professional career, he has published over 80 papers on diseases of potato, onion, and cabbage, 56 of these papers being concerned primarily with potato diseases. Thirteen students have beeen privileged to study for their Doctor of Philosophy degree in Dr. Larson's laboratories.

Mr. Chairman, it is a real privilege and a pleasure to introduce our friend and respected associate Dr. R. H. Larson at the 1960 annual recognition dinner for Honorary Life Membership in the Potato Association of America.

W. J. HOOKER

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## Announcement

**The 1960 Annual Meeting of the American Society of Agronomy will be held December 5-8 in the Morrison Hotel, Chicago, Ill.**

## COMMITTEE REPORTS
## POTATO ASSOCIATION OF AMERICA

Spurgeon Chapel, American Baptist Assembly
Green Lake, Wisconsin

Monday, August 29, 1960

9:00 P.M. — Meeting called to order by President Paul Eastman.

Program Committee by R. L. Sawyer. Forty-three papers concerning all phases of potato investigations were presented. Seven of these papers were part of a symposium on potato processing.

*Membership Committee* report by John Campbell.

*Editorial Board* report by John Campbell.

*Handbook Committee* report by Robert Akeley.

*Policy Committee* report by Robert Hougas.

*Late Blight Investigations Committee* report by Keith Graham.

*Virus Diseases Committee* report by James Monroe.

*Potato Utilization Committee* report by Ora Smith.

*The Committee on Standards* report by: A. Hawkins, O. Smith, D. Young, I. Feustel.

*Potato Nutrition Committee* report by R. Akeley.

*Committee Report on Genetics and Cytology.* Remarks by S. J. Peloquin.

*Crest and Seal* report by J. Campbell.

*Honorary Life Membership Committee* report by W. Hooker.

*Coordinating Committee* report by O. Turnquist.

RICHARD L. SAWYER, *Secretary*

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## EXECUTIVE COMMITTEE MEETING
## POTATO ASSOCIATION OF AMERICA

Monday, August 29, 1960

7:30 P.M. — Meeting called to order by P. Eastman.

Members present: P. Eastman, J. Campbell, O. Turnquist, C. Cunningham, R. Akeley, W. Sparks, R. Sawyer.

Discussion of future potato association meetings. Would like to meet earlier and possibly by ourselves. General recommendations that the Potato Association go west next year and meet in late July or early August.

Unanimous approval for the purchase of a postage meter.

J. Campbell announced increasing cost, for 1961, of publication of the Journal of 10%.

Discussion of Handbook Committee report. General agreement that their recommendations on subject matter handling be followed. O. Turnquist suggested a meeting of all committees be scheduled on the annual program prior to the committee reports session. O. Turnquist suggested and general agreement given that some committees are too large.

Discussion on Nomenclature. O. Turnquist suggests there should be a new committee.

Abstract and secretarial fees. Bill submitted of $79.00 for abstract and secretarial fees for setting up program. Voted to pay it.

Honorary Life Membership. It was suggested that Life Members wear their badges so people would know and recognize them. Unanimous agreement that next year's considerations remain two tecehnical and one non-technical workers.

No one was in favor of renewing affiliation with AIBS at the present time.

*Seal*—general agreement that the seal should be accepted but further work be done on a crest.

RICHARD L. SAWYER, *Secretary*

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## ANNUAL BUSINESS MEETING
## POTATO ASSOCIATION OF AMERICA

Wednesday, August 31, 1960

Secretary's report by R. L. Sawyer. Report accepted. Motion made by Paul Mosher and seconded by Robert Akeley.

Treasurer's report by J. C. Campbell. Report accepted. Motion made by J. C. Campbell and seconded by D. Isleib.

Auditing Committee report by D. Isleib. Report accepted. Motion made by W. Sparks and seconded by R. Hougas.

Seal and Crest. Voted to accept seal. Motion made by Walter Sparks and seconded by J. Campbell. It was voted to further investigate a crest. Motion made by L. Dionne and seconded by W. Sparks.

Standards Committee, A. Hawkins reporting. Resolved that the Potato Association of America request the assistance of the Regional Laboratories to provide a standardized method of determining specific gravity by weight in air and water and provide a conversion table for converting specific gravity to dry matter. The Potato Association of America to contact the Chairman of the Potato Advisory Committee advising of the need for a standardized procedure and conversion table. In the interim the committee recommends that the method of determining specific gravity and the conversion table used for converting to dry matter be stated with each report. Report accepted. Motion made by C. L. Fitch and seconded by J. Haddock.

Handbook Committee report by R. Akeley. R. Akeley briefly discussed the recommendation that the handbook contain information which would bring up to date all phases of potato production annually. Committee chairmen are responsible for bringing each section up to date. This still leaves room for yearly accent on a given subject. Recommendation accepted. Motion made by W. Sparks and seconded by J. Haddock. Vote was 12 against 16 in favor.

Next year's meeting. Paul Eastman reported that a desire to go west and hold the meeting the last of July or early August had been expressed by a number of people. There is an invitation by H. Werner to meet at Lincoln, Nebraska on record. G. Rieman suggests the Executive Committee explore the possibility of going to New Jersey. W. Sparks suggested the Red River Valley be considered. Several folk spoke in favor of meeting with other groups and several spoke in favor of meeting by ourselves. L. Dionne moved that the Executive Committee explore the

possibilities and come to a conclusion. J. Campbell seconded the motion and it was accepted.

C. L. Fitch reported on the need for a potato breeding program and explained the political moves involved in allocations.

Resolutions Committee report was presented by R. V. Akeley. The following resolution was adopted.

BE IT RESOLVED THAT: The members of the 44th Annual Meeting of the Potato Association of America wish to express their sincere thanks to the American Phytopathological Society, the local Arrangement Committee, and to the American Baptist Assembly at Green Lake, Wisconsin for the excellent arrangements and many courtesies extended to us and our families. Motion was made by J. Haddock for acceptance and seconded by J. Campbell, and was carried.

Ora Smith reported on a California couple who do a good job on bibliography compiling.

Paul Eastman designated W. Hooker as official representative of the American Potato Association to the European Potato Association meeting in 1960, O. Smith and R. Hougas were designated as alternates.

A. Hawkins suggested that in voting for Honorary Life Memberships, no voting member should have to vote for more than he wishes to have the nomination. D. Isleib moved this suggestion be referred to the Honorary Life Membership Committee, seconded by A. Hawkins and motion carried.

Nominating Committee presented by A. Hawkins. Following slate of officers presented. *President,* O. C. Turnquist; *President-Elect,* R. V. Akeley; *Vice President,* L. C. Young; *Secretary,* R. L. Sawyer; *Treasurer,* J. C. Campbell; *Director for 3 Years,* R. H. Treadway. Motion made by Paul Mosher that the Secretary cast one ballot for this late of officers and that nominations cease. Seconded by D. Merriam and carried.

G. Rieman wished to know how easy it has been to get the Executive Committee together this past year. P. Eastmen reported no problem.

L. C. Young presented a balance of between $200 and $300 to the Potato Association to establish a speaker fund to pay expenses for speakers unable to attend meetings. This balance was from sums collected to defray costs of the Potato Meetings in Canada. L. C. Young suggested that the Potato Association add to this fund and establish it on permanent basis. J. Campbell put the suggestion in the form of a motion that a similar sum be added by the Potato Association, and J. Haddock seconded and motion carried.

Meeting adjourned by P. Eastman.

RICHARD L. SAWYER, *Secretary*

## FINANCIAL REPORT

## THE POTATO ASSOCIATION OF AMERICA

August 1, 1959 to July 31, 1960

### RECEIPTS

| | | |
|---|---|---|
| Balance in checking account, July 31, 1959 | $5,328.47 | |
| Annual dues | 6,608.62 | |
| Sale of advertising in Journal | 2,907.87 | |
| Sale of reprints | 2,270.10 | |
| Sale of back issues | 617.43 | |
| Sale of binders | 139.50 | |
| Sale of Handbooks | 573.55 | |
| Sale of advertising in Handbook | 3,771.12 | |
| General | 97.84 | |
| TOTAL RECEIPTS | | $22,324.50 |

### DISBURSEMENTS

| | | |
|---|---|---|
| Printing Journal (12 issues) | 6,669.81 | |
| Mailing & supplies | 1,036.67 | |
| Printing reprints | 1,095.73 | |
| Purchase of back issues | 55.80 | |
| Salaries, E. Campbell (Bookkeeping, billing, etc) | 720.00 | |
| J. Campbell (Editing Journal) | 900.00 | |
| E. Clark (Proof reading Journal) | 330.00 | |
| Commission on Journal advertising | 509.66 | |
| Research for potato promotion (Douglass College) | 250.00 | |
| Purchase of binders | 241.56 | |
| Handbook expenses (Editing, printing, mailing) | 3,545.52 | |
| Stenographic & inventory work | 110.00 | |
| General (Meeting, bank charges, telephone, etc.) | 146.21 | |
| TOTAL DISBURSEMENTS | | $15,610.96 |
| Balance in checking account, July 31, 1960 | | 6,703.54 |

### SAVINGS ACCOUNTS

*Family Savings & Loan Association*

| | | |
|---|---|---|
| In bank July 31, 1959 | $2,086.19 | |
| Interest | 65.69 | |
| TOTAL | | $ 2,151.86 |

*Lelah Starks Fund*

| | | |
|---|---|---|
| In bank July 31, 1959 | 470.01 | |
| Interest | 11.82 | |
| TOTAL | | $ 481.83 |
| TOTAL CASH ASSETS, July 31, 1960 | | $ 9,337.25 |

## FINANCIAL REPORT ON THE 1960 POTATO HANDBOOK

| | |
|---|---|
| RECEIPTS | |
| Sale of Handbook advertising | $3,896.12 |
| Sale of Handbooks | 573.55 |
| Total receipts | $4,469.67 |
| DISBURSEMENTS | |
| Editing | $1,000.00 |
| Printing | 1,840.78 |
| Mailing | 120.32 |
| Commission on advertising | 584.42 |
| Total disbursements | $3,545.52 |

## REPORT OF THE HANDBOOK COMMITTEE

Your Committee has considered the future course of the Handbook and has the following recommendations to make:

1. That each issue be broken down into a number of categories. Suggested are: (1) Varieties (Breeding and Cytogenetics); (2) Seed Certification; (3) Machinery and Equipment; (4) Processing and Utilization; (5) Diseases and their Control; (6) Insects and their Control; (7) Nutrition and Culture; (8) Quality and Standards; (9) Transportation and Storage; and (10) Marketing and Packaging.

2. That these categories be handled by special committees whose chairmen will report annually to the Potato Association of America and who will also be responsible for writing up current information to be used in the Handbook.

The Potato Association now has special committees that cover most of the above categories. These committee reports could be rewritten and included each year in the Handbook. In that way each issue would contain something of interest to everyone interested in potatoes.

The appeal of the Handbook would be greatly widened, especially if it were published as a type of buyer's guide. There is much information that could be included each year, such as information on marketing, seed certification, processing, and production summaries published by government agencies.

With the suggested set-up, circulation of the Handbook could be enlarged through attractive advertising in farm and trade journals. This would also help to obtain advertising for the Potato Handbook in the future.

Committee members:

R. V. Akeley
O. C. Turnquist
John C. Campbell
P. J. Eastman

## REPORT OF THE LATE BLIGHT INVESTIGATIONS COMMITTEE

The principal activity of the Late Blight Investigations Committee to be presented here is a report of a sub-committee consisting of Dr. K. M. Graham, chairman, Dr. M. E. Gallegly, and Dr. W. R. Mills. The sub-committee was appointed to consider the expansion or revision of the present system of nomenclature of races of *Phytophthora infestans*. The following is their report:

The Canadian races tentatively designated 1.2.3.4.5, 1.2.3.4.6, and 1.2.3.4.5.6 and the differential hosts presumed to carry genes $CR_5$ and $CR_6$ were distributed to Drs. Gallegly, Mills, Black and Schick while Dr. Mastenbroek received only the differentials. The results of preliminary tests conducted by Graham, Hodgson, Gallegly and Black revealed a few inconsistencies which may be traceable to variations in the inoculation techniques or to loss of virulence by certian of the isolates.

Neither Gallegly nor Black could get race 1.2.3.4.5 to attack $CR_5$ consistently, although Hodgson and Graham carry this race continuously on this genotype. In Gallegly's tests, none of these races attacked $CR_5$ while Black found that they attacked $CR_5$ and $CR_6$ but that they lost vigor when maintained on these genotypes. He could not distinguish between races 1.2.3.4.6 and 1.2.3.4.5.6. However, tests performed by Black with a number of other races indicated that $CR_5$, $CR_6$ and $SR_6$ (Schick's $R_6$) were all different. He also found that the 3 Canadian races attacked $SR_6$.

A number of Gallegly's blight-resistant selections presumed to carry a gene $GR_X$ were susceptible to races 1.2.3.4.6. and 1.2.3.4.5.6. However, they exhibited a degree of partial resistance which in the case of clones WV44-11 and WV57-7 was correlated with Mexican field readings of "2" and "3" respectively.

A population of seedlings of SRxyz (Schick's Rxyz) segregated for resistance races 1.2.3.4.6 and 1.2.3.4.5.6 in tests at Fredericton. This host was apparently true-breeding for resistance to all of Schick's races including those capable of attacking $SR_6$.

Gallegly's race 1.3.4.Y consistently produced a susceptible reaction on $CR_6$. Results of its reaction on the remainder of Gallegly's selections are not immediately available, but the circumstantial evidence indicates that $GR_Y$ and $CR_6$ are identical.

The evidence presently before the sub-committee shows the existence of 3 additional genes which in order of discovery would be $R_5$ (Canada), $R_6$ (Germany), $R_7$ (U. S. and Canada), plus further genes for resistance in certain seedlings of Schick's Rxyz and in Galleglys' selections of *S. demissum* origin. These conclusions are only tentative and subject to re-examination by the investigators concerned.

As part of the job of keeping the Potato Association up to date on progress in late blight research, the committee asked one of the members, Dr. J. R. Wallin, to prepare a summary of recent progress in predicting the occurrence of late blight epidemics. His paper will be submitted to the Editor of the American Potato Journal for publication.

The committee finds that besides the investigations covered in the

above reports, work is proceeding at various institutions along several other lines, including breeding for late blight resistance, especially field resistance, and on the sexual stage of the pathogen.

M. E. Gallegly
K. M. Graham
W. R. Mills
J. S. Niederhauser
J. R. Wallin
Carl J. Eide, *Chairman*

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## REPORT OF THE POTATO VIRUS INVESTIGATIONS COMMITTEE

Dr. D. S. MacLachlan, Chairman of this Committee, has resigned from his position in potato virus research, and simultaneously his activities within the Potato Association have ceased. Consequently this report, prepared at short notice, is not comprehensive. No attempt has been made to cover recent developments in potato virus investigations other than that supplied by members of this committee.

The following has been brought to the attention of the committee:

*Province of British Columbia.* There is an alarming increase in the amount of leaf roll prevalent in crops of Netted Gem as reflected by net necrosis of the tubers.

*State of Washington.* Chronic leaf roll has been found in growing crops in amounts above that expected, considering the areas that supplied the seed.

*State of Michigan.* It has been shown in East Lansing that potato plants infected with potato virus Y are more susceptible to early blight than are healthy plants of the same variety.

*State of Maine.* A new program of breeding for resistance to spindle tuber has been inaugurated. This year a total of 1751 seedlings from 12 crosses and 7 selfed lines are being tested for resistance to this virus. Four seedlings of promise were obtained from the 1959 tests.

During the past 15 years some 100,000 seedlings have been tested for leaf roll resistance. These tests have shown that certain crosses will produce seedlings with some valuable resistance to infection with this virus. Two seedlings with this resistance have now been obtained with good agronomic qualities.

*Province of New Brunswick.* Breeding for the hypersensitive form of resistance to viruses A, X, and Y has been in effect in the National Potato Breeding Project for some years. The most promising potential variety at the present time is hypersensitive to viruses A and X. Four seedlings with this form of resistance to several strains of virus Y are under test for commercial qualities.

As no report of the Potato Virus Committee has appeared in the American Potato Journal for some years perhaps there is need for the terms of reference of this committee to be broadened or revised. The changes recommended for the Late Blight Invstigations Committee in 1959,

and implemented in 1960, could be adopted by the Potato Virus Committee. A short vital report together with an abstract of a completed phase of work written for publication by one member as sole author could then be our most effective contribution each year.

W. G. Hoyman
Franklin Manzer
N. S. Wright
W. J. Hooker
James Munro, *Acting Chairman*


# IT PAYS TO BE HIDDEN HUNGER CONSCIOUS

Plants, like people, can suffer from hidden hunger — the period between the time they are in good health and in bad health. This is an insidious time because nothing *looks* wrong. The plant seems to be healthy — or certainly shows no signs of hunger. And then — almost suddenly, it seems — the plant crosses a point of no return as far as its finest yield and quality are concerned. Outward signs may never show — except in the yield. It's an insidious thing. Hidden Hunger! A problem requiring careful diagnosis and management that is always hunger conscious.

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